REPORT OF EXPERIMENTS

ON THE

GROWTH OF BARLEY

FOR TWENTY YEARS IN SUCCESSION ON THE SAME LAND.

By J. B. LAWES, Esq., F.R.S., F.C.S.;

AND

J. H. GILBERT, Ph.D., F.R.S., F.C.S.

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REPORT

OF

EXPERIMENTS ON THE GROWTH OF BARLEY

FOR TWENTY YEARS IN SUCCESSION ON THE SAME LAND.

In volumes viii. xii. and xvi. of the first series of the 'Journal of the Royal Agricultural Society of England,' we gave some account of experiments on the growth of Wheat year after year on the same land; in volume xxv. (1864), we published a detailed Report on the growth of the crop, without manure, and with different descriptions of manure, for twenty years in succession on the same land; and the twenty-ninth crop has now been harvested. In volume xviii. (1857), results on the growth of Barley, under somewhat similar conditions of manuring, for six years in succession on the same land, were given. Those experiments have been continued up to the present time, and are still in progress; and we are now enabled to record the results obtained with barley, as already with wheat, over twenty consecutive seasons.

Barley is, at any rate through the greater part of England, if not throughout Scotland and Ireland, the second in importance of the cereal grains we cultivate; in some localities, indeed, it is of first importance. It is a prominent element in the well-known four-course rotation, and is more or less prominent in almost every rotation throughout the greater part of the British Isles. Moreover, it is supposed that the characters and the condition of land under which it can be advantageously cultivated are greatly limited, and that its market value is much influenced, by certain fiscal arrangements. From various points of view, therefore. exact knowledge of the quantity and quality of the produce it yields, on a soil of a given description, but under a great variety of well-defined conditions as to manuring, and in seasons of very various characters, cannot fail to be of great practical interest.

The conditions of growth of barley, are, in some respects, very similar to those of wheat; but in others they are very different. Thus, as a rule, wheat is sown in the autumn, but barley not until the spring; and it has, therefore, much less time for the distribution of its roots, and for getting possession of the stores within the soil. Again, the descriptions of soil which are the most suitable for the growth of wheat, are generally not equally well adapted for the growth of barley. Hence, apart from the importance attaching to the barley-crop as a prominent and independent element in most of our rotations, the question of the degree in which the requirements and results of its growth are similar to, or different from, those of its botanical ally—wheat (both belonging to the same natural family, the *Graminaceæ*), is one of very considerable interest, both practical and scientific.

Little less interesting would it be, not only to compare the results obtained with winter-sown wheat and spring-sown barley, but to include in the comparison the likewise spring-sown oats, the third in importance among the corn-yielding plants of the graminaceous family cultivated in temperate climates. But the experiments on the continuous growth of oats have, as yet, only extended over a very few seasons; so that at present we can only incidentally and imperfectly make reference to them. There is, however, already sufficient indication that the results will, in due time, have considerable, both independent and comparative, value.

The first experimental wheat-crop, in the field in which the 30th in succession is now growing, was harvested in 1844; and, in the spring of 1845, about 10 acres, in an immediately adjoining field, were appropriated to somewhat similar experiments on barley. Owing, however, to the great amount of labour and attention that would be required in following them up with sufficient accuracy and detail, it was decided to rest satisfied for a time with the first year's clear indications. These were sufficient to show the great similarity, in some important respects, between the requirements and the conditions of growth of the two closely allied crops. But very much still remained to be learnt, and especially in regard to the equally important distinctions between the requirements of the two crops.

Much also was still wanting in the way of direct experimental evidence bearing upon the then opening "Mineral Theory" controversy; respecting the issues of which very few English agricultural readers are not, by this time, overwhelmingly satisfied. Indeed, the universal practical experience of British agriculture during the last quarter of a century of experiment, discussion, and general improvement, has entirely confirmed the views we have held on the subject, and published in the 'Journal;' whilst, our distinguished opponent has not only sought to associate with the term "Mineral Theory," a meaning totally different from that which attached to it in the well-known controversy, but, under cover of a change of nomenclature, has claimed, as consistent with his own theory, views directly at variance with those he formerly maintained, and in the main accordant with the facts and conclusions which we have brought forward in opposition to the distinctive views of his earlier writings. Some illustrations bearing upon these points will be incidentally given further on;

but considering how settled are the opinions now generally held on the subject in this country, and how changed are those of the author of the "Mineral Theory," it would be out of place to devote so much of either time or space to its discussion in our introductory remarks as has been suitable on former occasions. Still less will it be necessary to discuss the results obtained with barley very prominently in their relation to the points that were in controversy in the early years of the progress of the experiments.

The experiments on barley were re-commenced in 1852, and the twentieth crop in succession was harvested in 1871. The land selected was a portion of that immediately adjoining the experimental wheat field, on which the preliminary trials in 1845 had been made. About 4½ of the 10 acres were devoted to the purpose. The general character of the land is much the same as that of the wheat field, namely, "a somewhat heavy loam, with a subsoil of raw, yellowish red clay, but resting in its turn upon chalk, which provides good natural drainage." The wheat field has, however, as a matter of experiment, been artificially drained, but the barley field has not.

The custom of the locality, in the case of land of similar quality, is to take the barley crop after roots fed off by sheep. But it will be readily understood from the above description of the soil, that it is too heavy for this to be done with advantage in wet seasons. Nevertheless, good crops, both in point of quantity and quality, are so grown, on such land, in favourable seasons, and may, as a rule, be relied upon when barley is taken, not after folding, but after another corn crop.

The questions to be solved by the experiments on barley may be stated in the same terms as were employed in introducing the Report of the results obtained with wheat:—"What are the grain-yielding capabilities of such land?—what its powers of endurance?—in what constituents, or class of constituents, does it soonest show signs of exhaustion?—and how far will the answers arrived at on these points in reference to it, accord with, or be a guide to, those which would apply to any large proportion of the arable land of Great Britain when farmed in the ordinary way, with rotation?"

The Field Experiments on Barley.

The previous cropping of the land set apart in 1852 for the continuous growth of barley was as under:—

1847, Swedish turnips, with farmyard manure and superphosphate (the roots carted off).

1848, Barley.

1849, Clover.

1850, Wheat.

1851, Barley, with sulphate of ammonia.

It had thus already grown two corn crops in succession, and was, therefore, agriculturally speaking, in a somewhat exhausted condition for the after-growth of grain, and would, in the course of ordinary practice, be re-manured before growing another crop. It was, therefore, in a suitable state for testing the effects of different manures upon the crop, and for showing, by the results, in what constituents, or class of constituents, the soil had, by the previous cropping, become practically the most deficient.

The area of 4¼ acres was divided into 24 nearly square plots; most of which were exactly one-fifth of an acre each, but the remainder somewhat less. Two plots were left unmanured; one was manured every year with farmyard-manure; and others with different manures, which, respectively, supplied certain constituents of farmyard manure, separately or in combination.

We here repeat, in answer to objections recently reiterated (this time in Germany), that we believe comparative results obtained by growing crops year after year on the same land, without manure, and with different manurial constituents, singly and in admixture, are far better calculated to indicate in what constituent, or constituents, the soil is relatively deficient, so far as the available supply for the crop to be grown is concerned, than what is generally understood as an analysis of the soil. On this point it may be well to quote a paragraph from our paper on the growth of Wheat for twenty years in succession on the same land:—

"Our conclusion, as indicated in former papers, and frequently expressed in answer to the objections of chemical friends who had not paid special attention to the applications of chemistry to agriculture, was, that far more had yet to be done in determining the chemical and physical qualities of soils in relation to the atmosphere, and to manurial substances exposed to their action, as well as in perfecting methods of analysis, before comparative analyses could aid us much in deciding upon the relative productiveness of different soils, to say nothing of the still more difficult problem of estimating, by such means, the condition of fertility or exhaustion of one and the same soil at different times. Of late years very much has been done in these departments of investigation; still, as recent discussions abundantly show, far too little is even yet known of what a soil either is or ought to be, in a chemical point of view, to render the results of the analysis of soils directly applicable to the solution of questions such as those we had in view in our inquiry. But if our knowledge of the chemistry of soils should progress as rapidly as it has during the last twenty years, the analysis of a soil will ere long become much more significant than it is at present." ('Journal of the Royal Agricultural Society of England,' vol. xxv. p. 98.)

In accordance with the views here indicated, we have from time to time, from 1846 up to 1870, taken samples of the soils and subsoils of our different experimental plots, until the collection now comprises about 300 specimens. In a large proportion of these the nitrogen, and in some the carbon, has been determined. Some have been experimented upon at Rothamsted in other ways, and some at Munich by Baron Liebig's son, Hermann von Liebig, who requested to have samples for examination; and the whole are carefully prepared and preserved, with a view to more complete investigation whenever time will permit. Reference will be made further on to some of the results that have been obtained. It is, then, not the chemical examination of soils on a systematic plan, and by methods carefully arranged and well adapted for the solution of specific questions, that we have regarded as unimportant; but it is the mere determination, in accordance with antiquated theoretical ideas, of the ultimate percentage composition of a soil, without due regard to the condition in which the constituents exist, and by methods which do not give sufficiently accurate or comparative results, that we have considered of little value. In the mean time let us see whether the synthetic, as distinguished from the analytic method of enquiry, will not give as important and conclusive evidence as to the conditions and requirements of growth of barley, as it has done in regard to other crops.

General Description of the Manures employed.

It has already been said that the selection of manures for the experiments on barley was, in many respects, the same as that adopted for those on wheat. In reference to this point it may be useful, by way of illustration, to show the probable average amounts of certain constituents in what may be taken as fairly corresponding crops of wheat and barley. For this purpose we will assume a produce per acre of—

Wheat, 30 bushels, of 60 lbs. per bushel = 1800 lbs., and 3000 lbs. straw, = 4800 lbs. total produce;

Barley, 40 bushels, of 52 lbs. per bushel = 2080 lbs., and 2500 lbs. straw, = 4580 lbs. total produce;

which will contain, approximately, the following constituents:—

	In Corn.		In Straw.		In Total Produce.	
	Wheat.	Barley.	Wheat.	Barley.	Wheat.	Barley.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Nitrogen	32	33	13	12	45	45
Phosphoric acid ..	16	17	7	5	23	22
Potass	9·5	11·5	20·5	18·5	30	30
Lime	1	1·5	9	10·5	10	12
Magnesia	3·5	4	3	2·5	6·5	6·5
Silica	0·5	12	99·5	63	100	75

It will be observed that most of the above constituents (which, in the sense that they are those which are the most likely to become deficient in the soil, may be said to be the most important constituents of the two crops) occur in nearly equal amounts in the total produce of either. The most prominent exceptions are, that the total barley crop would remove rather more lime, but considerably less silica, than the wheat crop. But, looking to the grain alone, the barley is seen to remove considerably more of silica, and rather more of each other constituent, than the wheat. Therefore, in cases in which the grain only is sold, and the straw is returned to the land in due course as manure, the eventual loss to the soil would be upon the whole greater, especially in silica, by the growth of such a crop of barley than of such a crop of wheat. In the experiments now to be considered, however, both corn and straw are always entirely removed from the land.

In Germany, it has recently been urged against the plan of our experiments, that the amounts of the different constituents applied as manure, for the different crops, have no direct relation to the amounts which are annually removed from the soil in the crops. We freely admit that this is the case. We at the same time maintain that, with the existing knowledge at the time of the arrangement of the experiments—nay, even with present knowledge, or rather ignorance—of the reactions of the different manurial substances within the soil, of the consequent distribution and state of combination within it of the constituents they supply, and of how far, accordingly, they are available for the crop to be grown, it would be the merest pedantry to apply only so much of each constituent as had been, or was expected to be, removed in the crop. We have, indeed, followed the plan supposed by our critics, in isolated cases, with the view of testing the validity of the assumptions upon which it is founded, and the result has been most signal failure, so far as the amount of the resulting crop is concerned.

Both the description, and the amounts, of the manures actually employed for the barley, are recorded in full in the folding Table, No. XXIV. (facing p. 80), and in Appendix-Table I., p. 179. They are in many respects the same as were adopted in the wheat experiments; and, as in those experiments, the most available and convenient forms in which the different constituents occur in the market have been selected. Thus (omitting from the enumeration those supplied in farmyard manure and rape-cake), the different "mineral"* or ash-constituents were supplied as follows:—

* With regard to the use of the term "mineral" see vol. xxiv., pp. 506-8 (foot-note), and vol. xxv., p. 101 (and context), of the 'Journal'; also vol. xvi. pp. 447-8, and context.

Potass—as sulphate of potass.
Soda—as sulphate of soda.
Magnesia—as sulphate of magnesia.
Lime—as sulphate, phosphate, and superphosphate.
Phosphoric acid—as bone-ash, mixed with sulphuric acid in quantity sufficient to convert most of the insoluble earthy phosphate of lime into sulphate and soluble superphosphate of lime.
Sulphuric acid—in the phosphatic mixture just mentioned; in sulphates of potass, soda, and magnesia; in sulphate of ammonia, &c.
Chlorine—in muriate of ammonia.
Silica—as artificial silicate of soda.

Other constituents have been supplied as under:—

Nitrogen—as sulphate and muriate of ammonia; as nitrate of soda; in farmyard manure; in rape-cake.
Non-nitrogenous organic matter, yielding by decomposition carbonic acid, and other products—in farmyard manure, in rape-cake.

The artificial manure or mixture for each plot is ground up, or otherwise mixed, with a sufficient quantity of soil and turf-ashes to make it up to a convenient measure for equal distribution over the land. The mixtures so prepared are, with proper precautions, sown broadcast by hand; as it has been found that the application of an exact amount of manure, to a limited area of land, can be best accomplished in that way.

The Field Results.

The results obtained with barley will be arranged and discussed under separate heads, adopting much the same division of the subject as in the report on the experiments with wheat, but following a somewhat different order of illustration. Accordingly, they will be considered in Sections as under:—

I.—Quantity and quality of the produce obtained, by different descriptions of manure, in each of the twenty seasons; with summary statements of the characters of each season.

II.—Average annual produce obtained over many years in succession, by each description of manure employed.

III.—Amount of ammonia in manure (or its equivalent of nitrogen in other forms), required to yield a given increase of grain (and its proportion of straw), according to the quantity applied per acre, to the available supply of mineral constituents within the soil, and to the characters of the season.

IV.—Effects of the unexhausted residue from previous manuring (*both nitrogenous and mineral*) upon succeeding crops, loss of constituents by drainage, and some allied points.

V.—Comparison of the results with those obtained in other fields, and under other conditions as to cropping, manuring, &c.

VI.—Summary, and general conclusions, showing the practical bearings of the results.

On this plan, the consideration in Section I. of the fluctuations in the quantity and quality of the produce due to season, and in Section II. of the average results obtained by the different manures over many seasons, will bring before the reader the main facts of the field experiments as such. He will then be in a position to appreciate the great practical importance, and the great scientific interest, of the questions discussed in Sections III. and IV., and to judge of the value of the evidence brought to bear upon them.

Section I. Quantity and Quality of the Produce obtained in the different Seasons.

In the following comments on the quantity and quality of the produce obtained in each of the twenty seasons separately, the observations on the characters of the seasons themselves are founded, partly on Mr. Glaisher's quarterly reports, partly on our own, and partly on other records; and they, as well as those relating to the crops of the country, may be taken as in the main applicable, so far as such brief and general statements can be, to a considerable portion of the Midland, Eastern, and South-Eastern districts of England. It may be further explained that, to aid the study of the characters of the several seasons, and with a view to the statements given of them, Tables have been arranged showing the actual climatic statistics of the seasons, and also others of their indices, showing the relative order of the characters registered, comparing season with season.

A little consideration will show that this branch of the subject is not less intricate than it is important; and it can of necessity be but incidentally and incompletely treated of within the limits of such a paper as this. Thus, it is obvious that different seasons will differ almost infinitely at each succeeding period of their advance, and that, with each variation, the character of development of the plant will also vary, tending to luxuriance, or to maturation, that is, to quantity, or to quality, as the case may be. Hence, only a very detailed consideration of climatic statistics, taken together with careful periodic observations in the field, can afford a really clear perception of the connection between the ever fluctuating characters of season and the equally fluctuating characters of growth and produce. It is, in fact, the distribution of the various elements making up the season, their mutual adaptations, and their adaptation to the stage of growth of the plant, which throughout influence the tendency to produce quantity or quality. It not unfrequently happens, too, that some passing conditions, not indicated by a summary of the meteorological registry, may affect the crop very strikingly; and thus the cause will be overlooked, unless careful observations be also made, and the stage of progress, and tendencies of growth, of the crop itself at the time, be likewise taken into account.

Having regard to these considerations, and to the well-known fact—which is only their practical consequence—that those characters of season which are very unfavourable for land in poor condition, may be favourable to land in high condition, and *vice versâ*, such a selection from the results obtained in each year has been made as it was thought would best illustrate the influence of season on the productive effects of characteristically different conditions of manuring; and for each of the twenty seasons the produce of the same plots is taken for illustration.

In explanation of the abbreviated descriptions of the manures given in the Tables, it may be stated that—

The "farmyard manure" was made in the open yard, and did not contain the dung of animals highly fed on purchased food.

The "Mixed Mineral Manure" was composed, per acre per annum, of—

200 lbs. sulphate of potass (300 lbs. the first 6 years).
100 lbs. sulphate of soda (200 lbs. the first 6 years).
100 lbs. sulphate of magnesia.
200 lbs. bone-ash. } superphosphate of
150 lbs. sulphuric acid, sp. gr. 1·7 } lime.

The "Ammonia Salts" consist of an equal mixture of the sulphate and muriate of ammonia of commerce.

For the sake of easy reference, and for comparison with the produce in each individual season, there is given in Table I., on the following page, the particulars of the average produce over the 20 years, on each of the plots selected for illustration in this Section.

In passing, the significant fact may here be noted, that, over a period of 20 years in succession, ammonia-salts alone gave an average, per acre per annum, of 5 bushels more corn, and of 4 cwts. more straw, than the mixed mineral manure alone. Again, the ammonia-salts and mixed mineral manure together gave an average annual produce of about 19 bushels more corn, and 14 cwts. more straw, than the mineral manure

TABLE I.—Average Quantity and Quality of Barley per Acre, per annum, on selected plots. Twenty Years, 1852–1871.

Plots.	MANURES, PER ACRE, PER ANNUM.	AVERAGE PRODUCE, &c., PER ACRE PER ANNUM.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bushel.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
1 O	Unmanured	20	52·3	1133	11¾	2454	86·6
7	14 Tons Farmyard Manure	48¼	54·3	2768	28¼	5933	88·5
4 O	Mixed Mineral Manure, alone ..	27½	53·4	1550	14⅜	3162	96·4
1 A	200 lbs. Ammonia-salts, alone ..	32½	52·1	1840	18½	3919	89·2
4 A	Mixed Mineral Manure, and .. 200 lbs. Ammonia-salts	46¼	54·0	2630	28½	5817	83·2
4 AA	Mixed Mineral Manure, and.. .. 400 lbs. Ammonia-salts first 6 years 200 lbs. Ammonia-salts next 10 years 275 lbs. Nitrate Soda last 4 years..	49¾	53·4	2813	32⅜	6443	79·5
4 C	Mixed Mineral Manure, and.. .. 2000 lbs. Rape-cake first 6 years 1000 lbs. Rape-cake last 14 years..	47⅜	53·6	2698	29½	6002	83·0

alone; but only about 14 bushels more corn, and 10 cwts. more straw, than the ammonia-salts alone.

There can be no doubt, therefore, that in this, in an agricultural sense, already corn-exhausted soil, the available supply of nitrogen was much more readily exhausted than the available supply of mineral constituents, so far as the requirements for the growth of barley are concerned.

It may be stated at the outset then, that the results obtained with barley, so far show general accordance with those on wheat; and that those with both crops are entirely inconsistent with the "Mineral Theory," according to which it was maintained—"that the supply of ammonia is unnecessary for most of our cultivated plants, and that it may be even superfluous, if only the soil contain a sufficient supply of the mineral food of plants, when the ammonia required for their development will be furnished by the atmosphere."

We need hardly say that the sharp distinction, the direct antithesis, between the terms "mineral" and "ammonia," as used in the above sentence, was habitually adopted by Baron Liebig in his earlier agricultural writings*; in fact, the "Mineral Theory" which was so long in controversy, can hardly be more clearly stated in so few words, than in those just given, written by himself.

* For a few additional illustrations see foot-note pp. 506-8, vol. xxiv. part 2 of the 'Journal of the Royal Agricultural Society of England.'

Notwithstanding this, what does he say now? He ignores his former arguments and views. He repudiates the obvious meaning of the terms he employed. He attributes to his opponents ignorance of the fact that, in a special scientific sense, ammonia-salts are mineral substances. He says—"All the materials constituting the food of our cultivated plants belong to the mineral kingdom." And—"Sulphate of ammonia and sal-ammoniac are mineral . . . ." Thus, ammonia is now claimed as a mineral manure, instead of antithetic to it, as throughout his earlier writings; and, accordingly, he claims as consistent with his "Mineral Theory," any beneficial effects from the use of nitrogenous manures. He would, indeed, have it supposed by the rising generation of readers, and if possible established for the future, that the "Mineral Theory" of Agriculture which has been in controversy is the "Mineral Theory" of vegetation in general, according to which, as distinguished from the so-called "Humus Theory," all the food of plants is mineral.

Having made these fundamental changes, without acknowledgment of either change or error, he endeavours to divert the attention of his modern and future readers from his earlier works and editions, and insinuates that the error has been on the side of his opponents. Thus, in 1870, in the course of a disquisition on the claims of *truth* in scientific inquiry, he speaks of his long forbearance in reference to the opposition to his views on the theory of fermentation, the sources of muscular power, the formation of fat, &c., and, in agricultural chemistry, on the laws of the nutrition of plants and animals. But, he goes on to say, there is for every one a limit, when it becomes his duty again to contend for that which he holds to be true, and this is reached, when error has gained the victory, and scarcely a doubt is expressed that it may be the truth. Then, with more special reference to the controversy with ourselves, he proceeds—

"In this way it happened to my views on agriculture, on the causes of the exhaustion of soils, and the conditions of the restoration of their fertility; in the 16 years which elapsed between the sixth and seventh editions of my book, my doctrine was as good as buried, by the majority of practical agriculturists it was held to be completely refuted, which might well be quite unhesitatingly assumed since one of the most renowned Scientific Societies had bestowed its great gold medal upon my most persevering opponents, as a seal of their triumph over the mineral theory. With the publication of the seventh edition of my 'Chemistry in its applications to Agriculture and Physiology,' a refutation of my doctrine is no longer spoken of, and the younger generation of farmers, standing in a far higher scientific position, no longer comprehend how there was so much disputing and quarrelling over truths which now seem to them self-evident."*

Considering that the "Mineral Theory," about which there was so much "disputing and quarrelling" has in reality been so long both refuted and buried, and that its author not only seeks to repudiate it, but to adopt without acknowledgment the views of his opponents put forward in correction of his own, it would be only waste of the reader's time to repeat the process of refutation and burial in any detail here. But those who may be curious to examine into the history and the truth of the matter for themselves, we would refer to the third and fourth English editions of Baron Liebig's book (1843 and 1847), or to the German editions *prior to the seventh*, and to our own papers in Volumes xii., xvi., xxiv., and xxv. of the 'Journal of the Royal Agricultural Society of England.'

Before commencing the consideration of the individual seasons, it may be well to add, by way of preliminary statement, that in the comments on the varying quantity and quality of produce obtained by one and the same manure according to season, the comparisons of the produce of each separate season with the average of the twenty seasons, will be made with as little reference as may be needed to the question of how far the result may be affected by the use of the same manure year after year on the same plot. In accordance with the plan already given, this subject, of the degree, or the limit, of the effects of accumulation, or of exhaustion, by previous manuring and cropping, on the produce of succeeding seasons, will receive separate and full consideration in Section IV.

Lastly, it will be useful to bear in mind throughout, that, so far as the influence of *season* is concerned, the *quantity* of the produce depends greatly on the amount and the distribution of rain during the growing period; and the *quality* (proportion of corn and quality of corn), on a suitable adaptation of temperature. And, so far as the influence of *manures* is concerned, the

* The following is the paragraph from the original—

"In dieser Weise war es meinen Ansichten über den Feldbaubetrieb, über die Ursachen der Erschöpfung der Felder und die Bedingungen der Wiederherstellung ihrer Fruchtbarkeit ergangen; in den 16 Jahren, die zwischen der 6. und 7. Auflage meines Buches liegen, war meine Lehre so gut wie zu Grabe getragen, sie wurde von der grossen Mehrzahl der practischen Landwirthe für vollkommen widerlegt gehalten, was wohl ganz unzweifelhaft daraus entnommen werden dürfte, dass eine der berühmtesten wissenschaftlichen Gesellschaften ihre grosse goldene Medaille meinen beharrlichsten Gegnern zur Besiegelung ihres Triumphes über die Mineraltheorie verliehen hat. Mit der Veröffentlichung der 7. Auflage meiner 'Chemie in ihrer Anwendung auf Agricultur und Physiologie,' ist von einer Widerlegung meiner Lehre nicht mehr die Rede, und die jüngere, wissenschaftlich weit höher stehende Generation der Landwirthe begreift es nicht mehr, dass so viel Hader und Zank über Wahrheiten war, die ihnen jetzt als selbstverständlich gelten." (Ueber Gährung, über Quelle der Muskelkraft und Ernährung. Vorrede, pp. ix–x.)

quantity (luxuriance) depends greatly on the available supply of nitrogen within the soil, and the *quality* of the crop (tendency to form seed and to ripen), on the available supply of mineral or ash-constituents.

First Season, 1852.

November and December, 1851, were upon the whole fine, but colder than usual. January and February, 1852, were mild and wet; March dry and clear, but cold and frosty; April dry, with some hot sun, but a good deal of cold east wind; May variable, but also with a good deal of cold east wind; June very wet and cold; July very hot, with several heavy thunderstorms; August fine at the beginning, very wet in the middle, and fine and hot at the end; September fine until the 6th, when there was a heavy thunderstorm, with a good deal of rain, the rest of the month being variable, with prevailing low temperatures, but upon the whole not unfavourable. In June the dew point was below, but the degree of humidity of the air slightly above the average; in July the dew point was above, but the degree of humidity considerably below the average; and in August and September both dew point and the degree of humidity were below the average.

Thus, the early portions of the winter were, upon the whole, fine but cold; but the later for the most part mild and wet. Then followed drier weather, allowing of an early working of the land. The spring was, however, dry, cold, and backward; the early summer rainy and cold, and the maturing period variable, with a good deal of hot weather, and some heavy storms.

The winter-sown wheat crop was reported to be generally not deficient in bulk, but in many districts much blighted, mildewed, and grown; the result being a yield considerably below the average. Shortly before harvest, barley as well as wheat was reported to be a bulky crop, and to give upon the whole a fair promise, though the hot weather of July was tending to premature ripening, especially on the lighter lands; and the very variable weather of the maturing period greatly lessened the yield, and injured the sample.

The experimental wheat crop was much below the average in quantity of both corn and straw, and also considerably below the average in quality of grain. Table II. (p. 18) exhibits the results obtained on the selected plots in the experimental barley field.

The weather was favourable for the preparation of the land, and the seed (Chevalier) was sown on March 5. The quantity of produce, both corn and straw, was, without manure, by mineral manure alone, and by ammonia-salts alone, considerably greater in this first season than on the average of the 20 years under the same continued conditions as to manure. The comparatively

TABLE II.—Quantity and Quality of Barley on Selected Plots. First Season, 1852.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bushel.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	33	52·8	1844	18½	3920	88·8
1 O	Unmanured	27¼	52·1	1585	16⅝	3445	85·2
4 O	Mixed Mineral Manure ..	32¾	51·5	1819	19½	4008	83·1
1 A	200 lbs. Ammonia-salts ..	36⅞	50·7	2088	22⅞	4652	81·5
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	40¾	51·4	2368	27⅞	5487	75·9
4 A A	Mixed Mineral Manure, and 400 lbs. Ammonia-salts ..	45⅛	50·6	2532	28⅜	5714	79·6
4 C	Mixed Mineral Manure, and 2000 lbs. Rape-cake ..	38	51·4	2098	24⅛	4796	77·7

large produce without manure, and by mineral manure alone, in the first year, shows that there was a quantity of unexhausted nitrogen from previous manuring available within the soil. The larger produce by ammonia-salts alone in the first than over the 20 seasons shows, in like manner, a comparative exhaustion of available mineral constituents in the later years. On the other hand, in the case of the farmyard manure, and the artificial manures in which there was annually supplied an abundance of mineral constituents as well as ammonia, or nitrogen in some form, the average produce of the 20 years considerably exceeded that of the first year. Part of this latter result is doubtless due to accumulation from year to year; but no doubt it is also in great measure due to the comparatively defective productive characters of the first season. This conclusion is confirmed by the fact that, the quality of the produce, as indicated by the weight per bushel, was, both from the deficiently and from the liberally manured plots, considerably below the average. The proportion of corn to straw was also in most cases below the average.

The results obtained in the experimental field are accordant, therefore, with those over a considerable area of the country, in showing that the variable, but upon the whole wet and cold season of 1852, was unfavourable to the barley crop, and especially so in point of quality.

Second Season, 1853.

Up to the middle of January, the winter of 1852-3 was, upon the whole, very unseasonably warm and wet; the rest of January, February, and March, were very cold, with a good deal of east and north-east wind, and some snow; April and May were for the most part cold and wet, with the exception of a short period in the middle of each month; June was variable, with a good deal of rain and cold wind; the greater part of July was excessively wet, with low temperatures, but the end of the month, and the beginning of August, were fine; the remainder of August, and September, were dull, unsettled, wet, and cold. Both the dew point and the degree of humidity of the air were generally, and, especially the latter, sometimes considerably below the average in June, July, August, and September.

Thus the autumn and early winter were exceedingly wet; so much so, indeed, that a considerable breadth of the land intended for wheat could not be sown. The remainder of the winter, and the spring, were for the most part unseasonably cold, or cold and wet; so also were the summer, and the harvest time, with the exception of a short period at the end of July and the beginning of August.

The wheat crop was reported to cover a very limited area, and to be far inferior to that of any season for many years past. Barley and oats were, however, sown over an unusually large area, and neither crop was reported to have suffered anything like so much as wheat.

The experimental wheat was not sown until the spring, and its crop was one of the worst that has been obtained up to the present time. The experimental barley was not sown until April 11; and the following are the results obtained on the selected plots:—

TABLE III.—Quantity and Quality of Barley on Selected Plots. Second Season, 1853.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bushel.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	36⅛	51·6	2136	22¾	4682	83·9
1 O	Unmanured	25¾	51·4	1552	18	3562	77·2
4 O	Mixed Mineral Manure ..	35⅝	52·1	2017	20½	4312	87·9
1 A	200 lbs. Ammonia-salts ..	38⅝	52·4	2285	23¾	4950	85·7
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	38¼	53·1	2309	26⅝	5284	77·6
4 A A	Mixed Mineral Manure, and 400 lbs. Ammonia-salts ..	44½	51·4	2590	31⅝	6134	73·1
4 C	Mixed Mineral Manure, and 2000 lbs. Rape-cake.. ..	40⅛	50·4	2302	27½	5386	74·6

Under the influence of this unusually cold and wet season, the weight of total produce (corn and straw together) was, without manure, and with the partial manures, that is, with mixed mineral manure alone, or ammonia-salts alone, rather more than in the first season, and very considerably more than the average of the 20 seasons. With farmyard manure it was considerably more than in the first season, but considerably less than the average. With the more complete artificial manures, supplying mineral constituents in abundance as well as ammonia, there was a considerable deficiency compared with the average; and more in the corn than in the straw. This comparatively worse result in the cold and wet season with the more liberal, than with the more partial manuring, is in great measure to be explained by the fact, that all the heavier crops were very much more laid than the lighter ones. Accordingly, the weight per bushel of dressed corn, which was in almost every case considerably lower than the average, was, so far as the artificial manures were concerned, the lower the higher the proportion of nitrogen to the mineral constituents in the manure; that is to say, the more the tendency to luxuriance, or quantity of gross produce, prevailed over that of seed-forming and ripening.

The results as a whole are an illustration of that which common experience teaches, namely, that with a cold and wet season the naturally light and poor, and the poorly manured lands, suffer much less than the naturally better, or more liberally manured soils. Another point of general interest is, that spring-sown corn as a rule suffers much less in such a season than the winter-sown wheat. Indeed, an amount of spring and summer rain which may be essential for the luxuriant growth, and subsequent yield, of the late-sown barley or oat crop, will frequently be adverse to the yield of the winter-sown wheat crop.

Third Season, 1854.

The winter of 1853–4 was, until past the middle of February, upon the whole unusually severe, with a good deal of snow; March and the greater part of April were very fine, but at the end of the latter month there was severe frost for the period, and a good deal of cold north wind; May was variable, generally cold and backward, with a good deal of rain; June was generally fine, but cold; the first half of July was also cold, with a moderate amount of rain; then came a week or two of fine hot weather, which was succeeded by thunderstorms and heavy rain; the beginning of August was wet, the middle fine though not warm, but the end dry and hot; September was almost throughout fine and favourable for getting in the crops, with high day, though low night, temperatures. In June, July, August, and September, the dew point was below the average, and the degree of humidity of the air was, in June above, in July about, and in August and September below, the average.

The autumn seed-time had been very favourable; it was followed by an unusually severe winter, but the spring seed-time was not unfavourable. This was succeeded by generally fine but generally cold and backward weather, until the middle of July, from which time, however, until harvest, the period, though changeable, embraced some fine maturing and harvest weather.

The season of 1854 appears, therefore, by the climatic records, to have been by no means continuously favourable, and the harvest was late; yet the wheat-crop of the country was reported to be one of the largest yield per acre for many years past. The barley and oat crops were also spoken of as generally very good.

The experimental wheat-crop was as remarkable for superiority in almost every particular, both of quantity and quality, as that of 1853 had been in the opposite direction. The following results were obtained in the experimental barley field:—

TABLE IV.—Quantity and Quality of Barley on Selected Plots. Third Season, 1854.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bushel.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	56⅜	53·9	3127	37¼	7298	75·0
1 O	Unmanured	35	53·6	1963	21¾	4405	80·4
4 O	Mixed Mineral Manure ..	42	54·0	2374	23⅛	4969	91·5
1 A	200 lbs. Ammonia-salts ..	47¾	53·6	2763	30¼	6155	81·5
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	60⅝	54·3	3428	40½	7958	75·7
4 A A	Mixed Mineral Manure, and 400 lbs. Ammonia-salts ..	62¾	52·1	3539	49	9026	64·5
4 C	Mixed Mineral Manure, and 2000 lbs. Rape-cake ..	60¼	52·8	3413	42⅛	8125	72·4

The seed was sown as early as February 24th; and the season, though backward, was without material checks. The result, with the early start, and these conditions, was a great bulk of produce, which, for its amount, was comparatively little laid; and, with favourable harvest weather, it finally yielded a large amount of corn as well as straw, and generally a good weight per bushel. Under every condition of manuring the produce was considerably higher than in either of the two preceding seasons, and considerably higher also than the average of the 20 seasons. It was, in fact, under most of the conditions of manuring, in straw higher, and in corn also higher than, or nearly as high as, in any of the 20 years. In 3 of the selected cases the produce exceeded 60 bushels of dressed corn, and 2 tons of straw, per acre. The season of 1854 was, therefore, one of remarkable productiveness; and it was remarkable for yielding such large crops under climatal conditions which the mere meteorological registry did not indicate to be peculiarly favourable. The result would appear to have been owing, as in the also remarkable season of 1863, to a continuity of unchecked growth, rather than to any special aptitude for unusual luxuriance at particular periods. Lastly, although the quantity of grain per acre was very large, the proportion of corn to straw was considerably below the average. It is probable, indeed, that the great yield was due to favourable conditions of season at the time of seed-forming, acting upon a great bulk of plant, and not to conditions favourable to seeding tendency through any lengthened period of growth.

Fourth Season, 1855.

The winter of 1854-55 was generally fine and mild up to the middle of January. Then came some frosts and deep snow; and the frost, with occasional snow, rain, and thaw, lasted, with more or less severity, through February and March. The beginning and end of April were also cold and frosty, and the month was more or less windy throughout, with dry east winds at the close. May and June were for the most part very cold and dry, with the exception of a short interval in the middle of that period, and the end of June, which was very hot; July was very variable, with many fine hot days, but with severe thunderstorms, and, upon the whole, a great excess of rain. The beginning of August was also wet, but the remainder of the month was fine; September also was fine, but cool. In June, August, and September, both the dew point and the degree of humidity of the atmosphere ranged low, but in July both were somewhat in excess of the average.

Thus, the latter part of the winter, and the early spring, were extremely severe; the remainder of the spring and the early summer cold and dry; July was very variable, with a great deal of rain, and a rather humid atmosphere; but the harvest period was more favourable.

With these characters of season, the wheat crop of 1855 was reported to be much less abundant than that of 1854; in quantity about, or but little over, an average—in quality very various, and in many cases much damaged. Barley was reported to be abundant, but damaged, yielding a bad malting sample.

In the experimental wheat field, the season of 1855 was one of average productiveness with moderate manuring, but was unfavourable for high manuring, that is for the growth and maturing of large crops. The selected plots in the experimental barley field gave the following results:—

TABLE V.—Quantity and Quality of Barley on Selected Plots. Fourth Season, 1855.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bushel.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	50⅛	52·9	2765	27½	5852	89·6
1 O	Unmanured	31	52·4	1773	17⅝	3745	89·9
4 O	Mixed Mineral Manure ..	37⅛	53·1	2067	18	4082	102·6
1 A	200 lbs. Ammonia-salts ..	44½	51·8	2443	24⅛	5148	90·3
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	48⅜	52·0	2659	31	6134	76·5
4 A A	Mixed Mineral Manure, and 400 lbs. Ammonia-salts ..	49⅝	48·9	2582	39⅞	7054	57·7
4 C	Mixed Mineral Manure, and 2000 lbs. Rape-cake ..	51¾	49·5	2783	37⅝	6993	66·1

A wet and warm July, and the beginning of August also wet, following upon a cold and dry spring and early summer, and, therefore, acting upon a backward crop, ensured a considerable bulk of produce; and with comparatively favourable conditions immediately before harvest, the quantity of corn per acre, as well as that of straw, was also above the average of the 20 years; excepting in some of the cases of the heavier crops, which were much laid. The corn-yielding characters of the crop varied, however, very considerably; the proportion of corn to straw, and the weight per bushel of the dressed corn, being generally considerably the lower, the greater the proportion of nitrogen to mineral constituents in the manure; that is to say, the more the manures supplied the conditions favourable to luxuriance and bulk, rather than to seeding tendency. Thus, by mineral manures alone, there are only 37⅛ bushels of corn, and 18 cwts. of straw, but 102 parts of corn for 100 of straw, and more than 53 lbs. weight per bushel; whilst with the same mineral manure and 400 lbs. ammonia-salts per acre, there are nearly 50 bushels of corn, and nearly 40 cwts. of straw, but less than 58 parts of corn to 100 of straw, and less than 49 lbs. per bushel. The very varied conditions of manuring supplied in the experimental field have, therefore, furnished, in their results, a striking illustration of how differently the same conditions of season may affect the produce of light and of heavy, or of deficiently or highly manured land; and how an excess of rain during the actively growing period may be beneficial under bad, and injurious under good agricultural conditions.

Fifth Season, 1856.

After a wet autumn, and some severe weather in the early part of the winter, January 1856 was very variable, but, upon the whole, mild, as was also February; March was dry and cold, with piercing north-east winds; April and May generally cold, and May particularly, very wet; June and July changeable as to temperature, with little rain, and frequently very cold nights until nearly the end of the latter month, which, with the beginning of August, was fine and hot; then came heavy thunderstorms with excessive rain, but the end of August, and the first half of September, were fine, after which again succeeded thunderstorms and heavy rain, the temperature being generally low throughout the month. The mean dew point, and degree of humidity of the air, were above, or about, the average in June, July, and August, and somewhat below it in September.

Thus, after a variable, but upon the whole, mild winter, the early spring was dry and cold, the remainder cold and wet, and the early summer cold and changeable, with little rain; then came a short interval of fine and hot weather, succeeded about the ripening period by very heavy rains and prevailing low temperatures. The harvest period was much broken, generally wet and unfavourable, especially in the later districts.

Wheat was reported to cover a large area; and shortly before harvest it was thought the crop would be over an average. Barley and oats were also expected to be over average per acre; though barley was said to cover an unusually small area. Eventually, however, owing to the unfavourable harvest-weather, and the deficiency of labour, a considerable proportion of all three crops was much damaged and badly got in.

The experimental wheat crop was, with liberal manuring, in quantity of straw over, and in that of grain fully equal to, the average; but it was unevenly and badly ripened, and the weight per bushel was low.

The results exhibited in Table VI. (p. 25) were obtained in the experimental barley field.

The barley was sown on March 8th; and with, for the most part, alternately cold and dry, and cold and wet, spring and summer, the amount of total produce was, under all conditions of manuring, very considerably below the average of the 20 years. The deficiency in quantity of corn was very great, and that of straw also great; though the less the higher the artificial manuring. With the farmyard manure, however, the deficiency

TABLE VI.—Quantity and Quality of Barley on Selected Plots. Fifth Season, 1856.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bushel.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	$32\frac{1}{8}$	47·1	1656	$19\frac{3}{4}$	3866	74·9
1 O	Unmanured	$13\frac{7}{8}$	49·1	812	$8\frac{3}{4}$	1797	82·4
4 O	Mixed Mineral Manure ..	$19\frac{3}{4}$	47·0	1018	$9\frac{3}{8}$	2075	96·3
1 A	200 lbs. Ammonia-salts ..	25	48·5	1432	$17\frac{1}{8}$	3347	74·8
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	$31\frac{3}{4}$	46·4	1599	$21\frac{1}{4}$	3981	67·1
4 A A	Mixed Mineral Manure, and 400 lbs. Ammonia-salts ..	$37\frac{5}{8}$	45·4	1886	33	5582	51·0
4 C	Mixed Mineral Manure, and 2000 lbs. Rape-cake ..	$35\frac{3}{8}$	46·3	1841	$30\frac{1}{2}$	5257	53·9

of straw was proportionally as great as in other cases of low produce. The quantity of corn was, indeed, under many of the conditions of manuring, the lowest, and under all nearly as low, as in any year of the 20; and, with a wet harvest time following upon an almost continuously unfavourable growing period, the proportion of corn to straw was unusually low, especially under the high manuring. The weight per bushel of dressed corn was also very much below the average, and almost throughout lower than in any other of the 20 seasons.

In former seasons it had been observed that, wherever phosphatic manures were used, the crop ripened much earlier than where they were not employed; but hitherto it had been thought desirable to cut all at the same time. From this time forward, however, there have generally been at least two cuttings, with an interval of from a week to a fortnight between them. In the case of the season under consideration, all the lots with phosphatic manure were cut on August 13th, after which there was a week of almost incessant rain, which much damaged both grain and straw, the former being much sprouted. The remainder of the plots were cut on August 29th, and being then dead ripe, were carted on the same day.

Judging from the reports, it would appear that the barley crop of the country generally was not so deficient in bulk as the results show that in the experimental field to have been; but it was probably in many cases equally damaged, and bad in yield.

Sixth Season, 1857.

The last quarter of 1856 was marked by rapid variations of pressure, and extreme changes of temperature. In January

(1857), there was a good deal of rain, and the greater part of the month was mild; but it became colder, with frost and snow, at the end of the month and the beginning of February. The remainder of February, and March, were very dry, with high barometer, frequent sharp frosty nights, and cold easterly winds. April was more rainy, but included also some fine though cold weather. May was fine, with a good deal of very warm weather, and but little rain. In June, again, there was a good deal of fine and hot weather; but there were also several thunderstorms, with heavy falls of rain, which were much needed, and thoroughly penetrated the soil. During July the weather was generally fine, and occasionally very hot, with much less than the usual amount of rain. In August there were several thunderstorms with heavy rain, but otherwise the weather was fine and remarkably hot. In the early part of September a great deal of rain fell, but the remainder of the month was fine, and its temperature was pretty uniformly rather above the average. In June, July, and August, though the dew point ranged somewhat high, the temperature did so in a greater degree, so that the atmosphere was drier than usual.

Thus, after a variable preliminary period, the beginning of the year was mild and wet; in the spring there was, upon the whole, a good deal of cold dry weather, but there was a sufficiency of rain in April. The summer was for the most part hot, with a dry atmosphere, but with genial and plentiful rains in June, and again in the beginning of August. Finally, the harvest period, though somewhat broken, was generally favourable.

The extent of land under wheat was reported to be less than in 1856; but with a summer hotter and drier than usual, though with occasional plentiful rains when most needed, the crop throughout promised exceedingly well; and, after harvest, it was estimated to have been unusually productive. Barley was said to cover a large area, but to be generally deficient in yield per acre, though proportionally less so in the best corn-growing districts of the country. Oats were pronounced to be decidedly below their average productiveness.

The experimental wheat crop, though by no means so bulky as many, was one of very much more than the average yield of grain per acre.

The results obtained with barley are shown in Table VII. (p. 27).

The seed was sown on March 6th. On all the plots having superphosphate in the manure, the crops were ripe earlier than on the others, and were cut on August 3rd, the rest being left till August 10th. In April there was a sufficiency of rain to

TABLE VII.—Quantity and Quality of Barley on Selected Plots. Sixth Season, 1857.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bushel.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	51¼	54·2	2915	23⅝	5564	110·0
1 O	Unmanured	26⅛	52·0	1453	12¾	2878	102·0
4 O	Mixed Mineral Manure ..	39¾	53·7	2191	17⅛	4111	114·1
1 A	200 lbs. Ammonia-salts ..	38⅞	51·9	2133	17¾	4118	107·5
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	57⅜	54·8	3216	27⅞	6336	103·1
4 A A	Mixed Mineral Manure, and 400 lbs. Ammonia-salts ..	64⅞	53·9	3677	36¼	7734	90·6
4 C	Mixed Mineral Manure, and 2000 lbs. Rape-cake ..	62¼	54·1	3536	33⅛	7241	95·4

establish growth; the summer was almost throughout hot and dry, excepting that there were some heavy falls of rain in June, and again in August; and the result was a crop of more than average bulk, and of very unusual seeding tendency. In fact, there was a higher proportion of corn to straw, and higher weight per bushel of corn, than in any other year of equal gross produce per acre. The season was remarkably favourable for high manuring; and even the heaviest crops, which were very heavy, especially in the ear, were very little laid. Thus, there were, with mineral manure and 400 lbs. of ammonia-salts per acre, 90½ parts of corn for 100 of straw, nearly 65 bushels of dressed corn per acre, and 53·9 lbs. weight per bushel. Again, with mineral manure and 2000 lbs. rape-cake, there were 95½ corn to 100 of straw, 62¼ bushels of dressed corn per acre, and a weight per bushel of 54·1 lbs.

The contrast between this season and its produce, and those of 1854, which was also a year of very unusual productiveness, is very great. Throughout the most active growing periods the temperature was very much lower in 1854 than in 1857. In May, 1854, there was about four times as much rain as in May, 1857; but in June and July there was less than half as much, though nearly as many rainy days. The consequence was very much more gross produce per acre, in 1854; and, with the highest manuring, about one-fourth more straw, but scarcely as much corn, as in 1857.

It would appear that the season of 1857 was much more strikingly favourable for the barley crop in the experimental field than, according to the published reports, it was estimated to be in the country generally. Thus, the crop was stated to be, upon the whole, of barely average yield per acre; though it was admitted to be good in the best corn-growing districts.

Seventh Season, 1858.

The last quarter of 1857 was generally mild, with unusually little rain during the last two months. January, 1858, was also dry, and, during the last fortnight, cold and frosty. February was cold, moderately rainy, with some snow, sharp frosts, and easterly winds, which extended some time into March; in which month there was comparatively little rain. The beginning of April was cold, but most of the remainder fine, and even hot; and a moderate amount of rain fell in the beginning and end of the month. It was also cold in the beginning of May, but fine, dry, and hot towards the end; though with heavy showers, making up about an average fall of rain during the month. June was upon the whole very fine, dry, and hot, with some heavy thunder-showers, but much less than the average amount of rain. In July there was much more rain; and, though variable, the weather was still upon the whole fine and hot. August and September were very fine, with much less than the average fall of rain. Throughout the quarter ending with September, as also in June, the degree of humidity of the atmosphere ranged lower than usual.

There was, therefore, during the winter, spring, and summer, upon the whole, much less than the usual amount of rain; though in February, April, May, and July, there were fair amounts. The air was also generally less humid than usual throughout the summer. The temperature, too, was generally above the average throughout the spring and summer months, whilst June was unusually hot.

Early in the summer the appearance of the wheat plant was generally that of great luxuriance, promising a bulky crop. The reports of the harvest indicated a crop, fully, if not above, the average, though by no means equal to the extraordinary one of 1857. Barley and oats were said to be very various, neither likely to give an average as to quantity; and barley not very good in quality.

The experimental wheat crop was pretty uniformly below the average in quantity of straw, but the produce of grain was generally above the average, and the more so the higher the manuring.

The results obtained with barley are shown in Table VIII. (p. 29).

Hitherto we have been able to show the effects of mixed mineral manure alone, the same with 200 lbs. ammonia-salts, the same with

TABLE VIII.—Quantity and Quality of Barley on Selected Plots.
Seventh Season, 1858.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	55	54·5	3118	31 3/8	6635	88·7
1 O	Unmanured	21 1/8	53·0	1207	10 7/8	2424	99·1
4 O	Mixed Mineral Manure ..	30 7/8	54·0	1780	16 1/8	3590	98·3
1 A	200 lbs. Ammonia-salts ..	31 1/2	53·0	1771	15 1/2	3506	102·1
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	51 1/2	54·0	2897	29 3/8	6192	87·9
4 A A	Mixed Mineral Manure, and 200 lbs. (¹) Ammonia-salts	56 1/4	53·5	3155	35 3/4	7160	78·8
4 C	Mixed Mineral Manure, and 1000 lbs. (²) Rape-cake ..	57 1/8	53·1	3162	35	7082	80·7

(¹) 400 lbs. the first 6 years (1852–7). (²) 2000 lbs. the first 6 years (1852–7).

400 lbs. ammonia-salts, and the same with 2000 lbs. of rape-cake per acre. The crops manured with 400 lbs. ammonia-salts, and 2000 lbs. of rape-cake, were, however, always obviously too heavy to stand up and ripen well in other than most exceptional seasons. For the crop of 1858, therefore, and subsequently, the quantity of rape-cake was reduced from 2000 to 1000 lbs. per acre. The quantity of ammonia-salts applied to the "A A" plots was, at the same time, reduced from 400 to 200 lbs. per acre; and this dressing was continued for ten years, namely, to 1867 inclusive, after which the 200 lbs. of ammonia-salts was substituted by 275 lbs. of nitrate of soda, which is estimated to contain the same quantity of nitrogen. From this time, therefore—1858 and afterwards—any increase of produce on plot 4 A A, over that on plot 4 A, (with only 200 lbs. of ammonia-salts per acre from the commencement), is, doubtless, in great measure, due to an unexhausted residue of nitrogen supplied in the 400 lbs. of ammonia-salts used annually during the preceding six years; and it will afterwards be seen that there was a marked effect from the previous excessive manuring, at any rate over ten consecutive seasons. In like manner, the produce on the plot manured with mineral manure and 1000 lbs. rape-cake in this and subsequent seasons, will be affected by the unexhausted residue from the excessive supply in the first six years.

The seed was sown on March 20; the earlier plots were cut on August 4, and the later ones on August 17. Thus, with a rather limited, but still a sufficient, supply of rain for the requirements of growth, and a comparatively hot summer and harvest period, the crops ripened somewhat early. There was, under most of the conditions of manuring, rather more than the average quantity of straw, more than the average proportion of corn to straw, especially with the most liberal manuring, notably more than the average quantity of corn per acre, and generally good, and full average, weight per bushel. Thus, under varied conditions of manuring, the season of 1858 was, in most particulars, one of more than average productiveness; but, in quantity of total produce, in proportion of corn to straw, and especially in quantity of corn per acre, it was considerably below that of the much hotter and pre-eminently *corn*-yielding season of 1857.

The experimental wheat-crop accorded pretty well in characters with that of the country generally; and the experimental barley-crop has much the characters of the experimental wheat-crop, namely, greater superiority in yield of corn than in produce of straw, when compared with the average; but the barley-crop of the country at large was, according to the reports, by no means so good as that in the experimental field is seen to have been.

Eighth Season, 1859.

The concluding quarter of 1858 was much drier than usual, and, during a considerable portion of it, it was very cold. The latter part of December, however, and January and February, 1859, were very fine and mild; March was also, upon the whole, mild, but with more rain; in April, too, a good deal of rain fell, and the latter part of the month was stormy, wet, and cold. May began with cold, dry, easterly winds; then came a good deal of rain, succeeded by fine and hot weather. During June there were several heavy thunderstorms, much rain fell, and the air was more humid than usual, though there was also some fine warm weather. July was, upon the whole, fine, and unusually hot; but there were several severe thunderstorms at the beginning and about the middle of the month. August was unsettled, but, for the most part, warm, with a good deal of rain. September was also unsettled, and cold, with an excessive amount of rain. In July the dew-point ranged high, but the temperature relatively higher; and, throughout the quarter ending with September, the degree of humidity of the air was below the average.

Thus, throughout the winter there was very little rain; and, with the exception of the early part, the weather was very mild. March was mild, with more rain; in April there was a full, in May a deficient, in June an excessive, in July a moderate, in August a full, and in September an excessive, supply of rain; whilst June and July were considerably above the average temperature, and the harvest period was generally unsettled, with a great deal of rain, and for the most part warm.

Early in the season the reports of the crops were, upon the whole, good; but the heavy rains of June laid the best of them, and the high temperature of that month, but especially of July, induced premature ripening; whilst, owing to the wet and stormy harvest period, and a deficiency of labour, much of them were too long out, and, especially the heavy ones, much damaged. Wheat was eventually pronounced to be under average, much injured, and very poor in quality: barley, a very uneven crop, with very thin grain, and a good deal sprouted; oats also very deficient.

The experimental wheat was unusually bulky with high manuring. With only moderate amounts of ammonia the quantity even of grain was not deficient; but, with heavy dressings of ammonia there was, compared with the average, a considerable deficiency of corn, and a large amount, and very undue proportion, of straw. The weight per bushel of dressed corn was also throughout very low. The following are the results obtained with barley:—

TABLE IX.—Quantity and Quality of Barley on Selected Plots. Eighth Season, 1859.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	40	52·5	2362	28½	5558	73·9
1 O	Unmanured	13½	49·0	775	9⅛	1800	75·6
4 O	Mixed Mineral Manure ..	19¾	52·5	1197	12¼	2567	87·4
1 A	200 lbs. Ammonia-salts ..	15⅜	47·5	919	11½	2204	71·5
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	34⅝	51·0	2017	27¼	5067	66·1
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	35¾	50·5	2092	30⅝	5517	61·1
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	35	51·0	2135	29½	5440	64·6

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852–7).

The seed was sown on March 3; and with, upon the whole, mild weather, and a good deal of rain, for a couple of months, succeeded by heavy thunderstorms, but a considerable amount of hot weather, the crop came forward very early, the plots manured with superphosphate being cut on July 13, and carted on August 1; whilst the remainder were not cut until August 8, and were carted on August 12. With the wet spring, and premature ripening summer, there was a considerable deficiency of total produce, which showed itself proportionally much less in the straw where the manure was liberal than where it was defective. The deficiency in quantity of corn was throughout very great, and the weight per bushel was also throughout low, and very low where superphosphate was not employed. The deficiency was the greatest in both corn and straw, and particularly in corn, where the ammonia-salts were used alone; that is to say, where there was the greatest excess of ammonia relatively to the supply of mineral constituents. The quantity of corn under that manuring was less than half, and that of the straw less than two-thirds, the average; and both corn and straw were absolutely less than in any either preceding or succeeding season, though this was only the eighth year of the twenty in which no mineral manure had been applied on that plot. Next to the plot manured with ammonia-salts alone, that continuously without manure was proportionally the worst in this season, compared with the average.

Thus, the general characters of the experimental barley crop, agree with those of the experimental wheat, in showing considerable deficiency; greater deficiency in corn than in straw, and greater where the manurial conditions were the most defective. The spring-sown barley suffered, however, more than the autumn-sown wheat; being not only more deficient in corn, but generally deficient in straw also, which the wheat crop was not. The comparatively greater deficiency of total produce of the barley, is probably due to the wet and warm weather, almost from the time of sowing. Sowing early would induce too much upward, and too little underground growth, thus leaving the plant without proper soil-resources in its later stages. The character of the experimental barley accords with that of the country generally, which, as has been seen, was stated to be uneven, prematurely ripened, and to yield thin grain, often sprouted.

Ninth Season, 1860.

The last quarter of 1859 was very variable as to temperature, but prevailingly cold; and upon the whole wet. January, 1860, was variable, but generally mild and wet; February was very cold, with sharp frosts and snow, ending with storms of rain and wind. The greater part of March was cold, with heavy showers, and snow; the remainder was finer and warmer. April was very cold, with some snow and sharp frosts; the beginning of May was also cold, but the rest of the month warmer than usual, though very wet. June was very cold and very wet; July also very cold, with a moderate amount of rain, most of which fell after the middle of the month; August cold and very wet, and September also cold, but fine in the early part, though very wet in the latter. In June, July, August, and September, the dew-point generally ranged low; but with the unusually low temperatures, the degree of humidity of the air was considerably above the average.

Thus, the winter was alternately very mild and very cold, and upon the whole very wet. The spring, summer, and autumn, were very stormy, cold, wet, and unseasonable; indeed, more so than had been known for many years past.

The crops were very backward, and the harvest 2, 3, or more, weeks later than usual. Wheat was, in some localities, not deficient in bulk, but generally very much damaged, yielding but a small proportion of grain, and that of very low quality. The crop was, indeed, very much below the average, both in quantity and quality. Barley and oats were reported to be bulky, and generally abundant; but barley especially in many districts much laid and damaged, and giving grain of inferior quality.

Under the influence of the extraordinarily wet and cold growing and ripening season, the wheat-crop in the experimental field was very much below the average both in quantity and quality, though the deficiency was proportionally less with the heavier dressings. The crop was generally worse than any other, excepting that of 1853. The following results were obtained in the experimental barley field:—

TABLE X.—Quantity and Quality of Barley on Selected Plots. Ninth Season, 1860.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	41⅝	52·1	2319	25⅜	5156	81·7
1 O	Unmanured	13¼	50·8	753	7½	1598	89·1
4 O	Mixed Mineral Manure ..	18¼	51·3	1013	9⅝	2093	93·8
1 A	200 lbs. Ammonia-salts ..	26⅝	50·8	1501	14⅞	3166	90·2
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	43½	51·1	2375	26⅝	5355	79·7
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	46¼	51·0	2501	29	5746	77·1
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	40¾	51·1	2238	22¾	4783	87·9

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852–7).

Bad as were the seasons of both 1859 and 1860, yet they show some remarkable contrasts. 1859 was wet, much rain falling in heavy storms, unusually warm, and very early, some of the plots in the experimental barley field being cut on July 13th. On the other hand, 1860 was wet, the rain a good deal distributed, unusually cold and sunless, all crops were very late, and the experimental barley, which was sown on March 19th, was not cut until September 3rd and 4th. In the wet, warm, and early season of 1859, there was a very great deficiency of corn, low weight per bushel, and comparatively little deficiency of straw, especially where the manuring was liberal. In the wet, cold, and late season of 1860, there was much less deficiency of corn, especially with liberal nitrogenous manuring, about as low a weight per bushel as in 1859, and a somewhat greater, but still not great, deficiency of straw. The wet, cold, and late season, gave, therefore, upon the whole, a much better crop, and especially much more corn, with liberal nitrogenous manuring, than the wet, warm, and prematurely early season.

This result is very instructive, when it is borne in mind that it is with high temperature, provided there be a sufficiency and not an excess of rain, that nitrogenous manures the most strikingly increase the produce of grain. We have here an illustration of the dependence of the result on the mutual adaptations of heat, moisture, and stage of growth of the plant, and of how difficult it is, without going into considerable detail as to each of these three elements, and their relations to one another, thoroughly to anticipate, or to explain, the influence of any particular season. It will be remembered that the very remarkable productiveness of 1854, was by no means clearly indicated in the general characters of the season, as represented in the summary statement of the meteorological registry for the period. Doubtless, an influential element of the restricted productiveness in 1859, with the higher temperatures, was the fact of their distribution being such as to bring the plant much too early to maturity, thus shortening its period of accumulation and growth. On the other hand, the much better result with the wet and cold season of 1860, was probably greatly due to the less active above-ground, and probably greater under-ground development, early in the season, and to a much more extended subsequent period of growth.

It is worthy of remark that, whilst, with mineral manures and ammonia-salts or nitrate of soda, the experimental barley crop was so much better in yield of grain in 1860 than in 1859, the experimental wheat-crop was, with similar manures, much the most deficient, both in corn and straw, in 1860. The winter-sown wheat having acquired much more complete possession of the soil than the spring-sown barley, the high temperature of the summer of 1859 would in a much less degree check its luxuriance and induce premature ripening—that is much less curtail its total growth—and hence, with liberal nitrogenous manuring we have, in its case, though a deficiency of corn, an even more than average total produce in the hot, but upon the whole wet, season of 1859; whilst with the barley there is a considerable deficiency of total produce, and more deficiency of corn than of straw. In the wet sunless season of 1860, on the other hand, the wheat, which requires higher temperatures for its luxuriance than barley, shows a great deficiency of total produce, more especially in the straw; and the barley less deficiency of total produce, and very much less deficiency of corn than in 1859. Lastly, it is remarkable, that although under the influence of the rapidly active artificial manures, there was such unusual deficiency of barley grain in the hot and early season of 1859, yet in the same season, the much less rapidly active, but much more comprehensive, manuring of farmyard dung gave a much less marked deficiency.

The results in the experimental fields are in accordance with the records of the crops in the country at large, in showing 1860 to have been for wheat a more, but for barley a less, adverse season than 1859.

Tenth Season, 1861.

October, 1860, was upon the whole seasonable; November very cold, with a good deal of rain; December mild at the beginning, but otherwise, as also the greater part of January (1861), extremely severe. Many evergreens of long standing were killed during this period. The remainder of January and February were much milder, with comparatively little rain; though during the latter month, as also pretty continuously through March, April, and the beginning of May, there was a good deal of cold wind, with less than the average fall of rain. The remainder of May was dry and fine, and even hot. June commenced with cold wind and rain, followed by an interval of fine and hot weather, and then a good deal of rain to the end of the month. July was generally seasonable as to temperature, with less than the average fall of rain. There was some heavy rain at the beginning of August, but, upon the whole, the month was very dry, fine, and favourable; and the fine weather continued, but with rather lower temperatures, and much wind, till nearly the end of September, when a considerable quantity of rain fell. In June, both the dew point and degree of humidity of the air ranged high; but in July, August, and September, they were not far from the average.

Thus, after, upon the whole, a favourable autumn seed-time, the winter of 1860–61 was unusually severe, and the young wheat-plant suffered considerably. The spring of 1861 was for the most part dry, with a good deal of cold wind; but plentiful rains, and some hot weather, in June, brought the growing crops rapidly forward; July, August, and the greater part of September, were, upon the whole, seasonable as to temperature and degree of humidity of the atmosphere, with less than the usual amount of rain.

The wheat crop was reported to be generally below the average in quantity per acre, owing chiefly to the loss of plant during the winter; but it was much improved by the favourable weather of the latter part of the summer, and the autumn; and a fair average, and, in many cases, good quality, compensated somewhat for deficiency of quantity. Spring corn crops were, however, stated to be generally good; both barley and oats, especially the latter, yielding very well.

The experimental wheat crop was considerably deficient in straw, and somewhat so in grain; but the quality of the latter was fully equal to the average. The crop was, however, in all respects superior to that of 1860; and generally in yield, but especially in quality of grain, superior to that of 1859 also.

The selected plots in the experimental barley-field gave the following results:—

TABLE XI.—Quantity and Quality of Barley on Selected Plots. Tenth Season, 1861.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	54⅜	54·8	3169	31⅝	6715	89·4
1 O	Unmanured	16¼	52·3	941	11	2166	76·8
4 O	Mixed Mineral Manure ..	29⅜	54·0	1648	15⅜	3366	95·9
1 A	200 lbs. Ammonia-salts ..	30½	51·5	1745	19⅝	3945	79·3
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	54⅝	54·0	3059	30½	6472	89·6
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	55⅞	53·5	3169	33⅝	6937	84·1
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	53⅝	54·3	3111	31	6576	89·8

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852–7).

Without manure, there was less than the average amount of both corn and straw; but, with every description of manure, there was more than the average quantity of straw, and with every description (excepting by ammonia-salts alone) more than the average quantity of corn; and with liberal manuring, whether in the form of farmyard dung, rape-cake, or mixed mineral manure and ammonia-salts, considerably more. The weight per bushel of dressed corn was also, in most cases, fully equal to the average.

Thus, although the winter-sown wheat had given less than an average yield, the spring-sown barley gave much more than an average. The wheat had suffered from the severity of the winter, which would doubtless be favourable, rather than otherwise, so far as the condition of the land for the barley was concerned. Both were subjected to the influence of a dry, cold, and backward spring, which would tend to root-development rather than early aboveground luxuriance. Plentiful rains following in June, and again at the beginning of August, with, upon the whole, seasonable temperatures throughout the greater part of June, July, and August, conditions favourable for both crops were supplied. Hence, notwithstanding a deficient plant, the wheat turned out better than was expected; and the barley being not too forward in its early stages, and, under the conditions of season, probably well rooted, gave, upon the whole, a much more than average crop, especially of grain. It should be added, that the riper crops, those with superphosphate of lime in the manure, were not cut until August 20th and 21st, and the remainder not until August 27th. The earlier crops were, for the most part, a little laid, but none seriously.

It will be seen that these results, obtained in the experimental fields, accord very well with those reported in regard to the crops of the country at large.

Eleventh Season, 1862.

October, 1861, was generally mild, fine, and dry; November inclement, with an excess of rain, and unusually low temperature. December was, upon the whole, warmer and drier than the average, but with a good deal of cold wind towards the end. January and February (1862) were, upon the whole, fine and dry, with a good deal of warmer, and but little of colder, weather than usual. The beginning of March was frosty, but the greater part unusually mild and wet. April was variable, with some unseasonably cold, but a good deal of warm, weather; and a full average amount of rain. May was extremely wet, and, in the early part especially, unusually warm. June, July, and August were, almost throughout, unsettled, with a good deal of wind and rain, and unusually low temperatures, the nights especially being frequently very cold; and although the atmosphere contained less than the average actual amount of moisture, the degree of humidity of the air was, with the low temperatures, not correspondingly low. September was also variable, with a good deal of rain at the beginning and end of the month, but with fine and warm weather intermediately.

The winter of 1861–2 was, therefore, upon the whole, mild. The spring was variable as to temperature, upon the whole warmer than usual, and very wet. The summer was unsettled, stormy, cold, and wet.

The wheat crop of the country was almost universally reported to be under the average, in many cases root-fallen, and also much mildewed. Barley was stated to be about, or scarcely, an average; oats a fair average.

The experimental wheat crops were, where the manuring was not excessive, fully equal to the average in both quantity and quality of grain, but, upon the whole, barely average in amount of straw.

The following results were obtained in the experimental barley-field:—

TABLE XII.—Quantity and Quality of Barley on Selected Plots. Eleventh Season, 1862.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c. Dressed Corn. Quantity.	Dressed Corn. Weight per Bush.	Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farm-yard Manure	49¾	54·8	2936	34¼	6774	76·5
1 O	Unmanured	16½	50·3	899	9¾	1987	82·6
4 O	Mixed Mineral Manure ..	25⅛	52·0	1428	13½	2941	94·4
1 A	200 lbs. Ammonia-salts ..	31⅜	49·4	1821	20⅜	4106	79·7
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	47⅝	54·0	2725	31⅝	6273	76·8
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	48¾	54·0	2824	33⅛	6529	76·2
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	45½	54·0	2634	28⅞	5872	81·4

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852–7).

As has been stated, March was unusually wet; the seed was not sown until April 16th; the earlier plots (those with superphosphate) were not cut until August 22nd, and the remainder not until September 1st. Excepting without manure, and with mineral manure alone, the quantity of barley-grain per acre was either close upon, or over, the average of the 20 years; and the weight per bushel of dressed corn was also, in most cases, fully or over the average. The superiority was the most marked with farmyard manure; and with it there was the greatest excess of straw as well as corn. With rape-cake, on the other hand, there was a slight deficiency of both straw and corn, the crops being more laid than any of the rest. With the more liberal artificial manures there was, however, fully or over the average quantity of both corn and straw. Upon the whole, therefore, notwithstanding the prevailing coldness and wetness of the summer, the experimental barley-crop was somewhat over average, in both quantity and quality, under liberal conditions of manuring. The barley-crop of the country generally was pronounced to have been much less injuriously affected than wheat, and to have been about, whilst the latter was seriously below, the average. The experimental wheat, however, as well as the experimental barley, turned out to be rather over the average.

Twelfth Season, 1863.

October, 1862, was unusually warm, but with a good deal of wind and rain. November was cold, with comparatively little rain. December, and January and February 1863, were unusually mild, with a fair amount of rain in December, a good deal in January, and but little in February. March was, upon the whole, mild, with but little rain, and wheat showed unusually forward growth. April was very dry and warm. In May there were some refreshing rains, though only a small total fall, but the temperature was occasionally extremely low, and pretty nearly throughout rather below the average, with frequent storms of wind. The temperature in June was also generally rather below the average, and there was a great deal of rain, which, though needed, and much aiding growth, was so heavy as to lay the most forward and bulky crops. In July there was much less rain than usual, with moderately high day but low night temperatures, and some sharp night frosts. August, with only moderate temperature, and about the usual amount of rain, was, upon the whole, favourable for ripening and for harvest. In September a good deal of rain fell, and the temperature ranged rather low. In June the condition of the atmosphere as to moisture was about the average for that month. In July, August, and September, both the actual amount and the degree of humidity were below the average.

Thus, the winter and early spring were generally very mild, with, upon the whole, less than the usual fall, but in January an excess of rain. The remainder of the spring included some warmer, but more colder weather than usual, and there was, upon the whole, a deficiency of rain. The early summer was also cool, with more, and some heavy rain. From that time to harvest, though the temperature was seldom high, it was (excepting some night-frosts in July) generally sufficient, the fall of rain was considerably below the average, and the atmosphere comparatively dry.

With these characters of season, the wheat crop of 1863 was almost unanimously reported to be considerably above the average, both in quantity and quality. Indeed, such a yield per acre had not been known for very many years. The plant came very early forward, had refreshing though limited rains in its early stages, received comparatively few checks, and with a somewhat cool but sufficiently warm summer, with little rain and a comparatively dry atmosphere during the latter stages of growth, and the ripening and harvest periods, there was a lengthened and almost unbroken course of gradual accumulation. Spring-sown crops, especially barley, were reported to be less uniformly good—those that were late sown having suffered for want of rain in the early stages of growth. Still, both barley and oats were considered to be rather over the average.

The experimental wheat crop of 1863 was the twentieth in succession on the same land, yet it proved to be in quantity of both grain and straw by far the most productive, and in quality of grain nearly the best, hitherto. It even considerably exceeded both 1854 and 1857, which also were years of extraordinary yield. It was a very favourable season for the action of ammonia-salts, giving more total produce, and especially more corn, for a given amount of ammonia applied, than was obtained in any other year. The following are the results obtained on the selected plots in the experimental barley field:—

TABLE XIII.—Quantity and Quality of Barley on Selected Plots. Twelfth Season, 1863.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c. Dressed Corn. Quantity.	Dressed Corn. Weight per Bush.	Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	59½	57·2	3473	33⅛	7185	93·6
1 O	Unmanured	22⅞	53·6	1276	11⅜	2545	100·5
4 O	Mixed Mineral Manure ..	33	54·8	1868	15⅜	3596	108·1
1 A	200 lbs. Ammonia-salts ..	42⅝	53·6	2406	21⅜	4806	100·3
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	55⅜	56·5	3210	32	6791	89·6
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	59½	56·4	3429	34¾	7323	88·1
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	54½	56·7	3159	30¾	6599	91·8

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852–7).

The barley was sown on March 11; the forwardest plots were cut on August 10 and carted on August 14, and the remainder cut on August 15 and carted on August 24. The seed was in, therefore, though not early, still in good time; and, with a mild but comparatively dry spring, the plant would probably distribute its feeders well through the soil, and with liberal rain in June, but no unduly forcing weather at any time, and favourable ripening and harvest periods, the result was, though not as with wheat in all respects the best crop hitherto, still one much over the average. It was so, especially in quantity and proportion of grain, whilst in quality, indicated by weight per bushel, it was actually the best up to that time; but, as will be seen, it has been exceeded on this point in several seasons since. In quantity of straw it was also over average. As in the case of wheat, the season was peculiarly favourable for the action of ammonia salts—indeed, for all high manuring—the farmyard manure giving not only considerably more than average total produce, but, both as to quantity and quality of corn, a better result than in any other season hitherto. Without manure, or with purely mineral manure, the amount of produce of both corn and straw has been exceeded in several seasons; but with mineral and nitrogenous manures together, the only years that exceeded or closely approached 1863 were, in produce of corn, 1854, 1857, and 1864; but, in produce of straw, 1854 the most strikingly, and less so 1855, 1861, 1862, 1864, 1869, and 1871.

A comparison between the characters of the seasons of 1854 and 1863, the former yielding, with high manuring, generally fully as much or more corn, and considerably more straw, than the latter, will usefully illustrate upon what conditions the very favourable, but still very different results of the two seasons depended. In 1854, which gave much the larger quantity of total produce of barley (corn and straw together), the winter having been very severe, the land was worked and the seed was sown very early; there was considerably less than half the average amount of rain in March, April, June, and July, with nearly double the usual amount in May. In 1863, on the other hand, the seed was not in so early; there was only about half the usual amount of rain in March, April, May, and July, with nearly double the usual amount in June. In both years there was in August about the average amount of rain. Almost throughout the six months enumerated, 1863 was slightly the warmer of the two, though both were rather warmer than usual in the early spring, and rather cooler than usual, but with a dry atmosphere, in the summer. Thus, both seasons were, throughout the greater part of the period of growth, comparatively dry and temperate; but each had, at one period, a large fall of rain, which, in 1854, yielding the largest amount of total produce, came in May, whilst in 1863 it did not come until June. It is worthy of remark, that with the winter-sown wheat the result was reversed; for with it the larger produce of both corn and straw—indeed the largest ever obtained—was in 1863. The difference is, however, explicable by the very different characters of the winters in the two cases. The winter of 1853-4 was unusually severe, and the wheat-plant backward in the early spring; whereas the winter of 1862-3 was mild, with a good deal of rain in January, and the plant was very forward in the spring. It would, therefore, the less require liberal rains before June than the spring-sown barley, and would be in a better state for benefitting by the generally favourable climatic conditions of the spring and summer than the less forward wheat-plant of 1854.

Thirteenth Season, 1864.

October, November, and December, 1863, were warmer than usual, with about, but upon the whole, less than the average amount of rain. January and February, 1864, though including some abnormally warm intervals, embraced longer periods of very cold and wintry weather, which checked forward vegetation; there was considerably less than the average fall of rain in January, and a very small fall, including snow, in February. In March the rainfall was large—the first half of the month generally warm, the latter half cold—and, upon the whole, the quarter had been very variable, colder than usual, with many alternations from frost to thaw. April and May were, for the most part, warm, with less than the average amount of rain; but the end of May and nearly the whole of June were comparatively cold, but with little rain. There was very unusually little rain in July and August, but an excess in September. The day-temperatures generally ranged high in July, but about the average in August and September; whilst the night-temperatures were somewhat below the average in July, much below in August, and about the average in September. In June and July the dew-point was below, and in August very much below, the average. The degree of humidity of the air was in June low, in July about the average, and in August very remarkably below the average.

Thus, the winter was very variable, including a good deal of warm, but also much very cold and wintry weather, though with comparatively little rain. The spring, though changeable and wet at the beginning, was, upon the whole, warm and dry; June was cold and dry, whilst the rest of the summer was hot in the day and cold at night, with very little rain, and in August especially a very dry atmosphere.

The wheat crop of the country proved to be, in quantity, much above the average on good soils, but below the average on poor soils, and in quality generally above the average. Barley was reported to be very unequal—good on good soils, stunted and poor on light soils—and, owing to the summer drought, the early generally much better than the late sown; upon the whole, however, over average. Oats irregular, short, deficient in yield, and generally much below average in quantity. Roots generally a failure.

The experimental wheat crop, though by no means equal to the extraordinary one of 1863, was nevertheless considerably above the average both in quantity and quality of grain, especially under liberal manuring; it was also much above the average in quantity of straw. The following results were obtained in the experimental barley field:—

TABLE XIV.—Quantity and Quality of Barley on Selected Plots. Thirteenth Season, 1864.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	62	57·4	3672	37⅜	7852	87·8
1 O	Unmanured	24	55·7	1379	12¾	2809	96·4
4 O	Mixed Mineral Manure ..	33¼	57·3	1949	16¾	3829	103·7
1 A	200 lbs. Ammonia-salts ..	38⅞	55·4	2258	20⅜	4533	99·2
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	55⅝	57·6	3316	34⅞	7225	84·8
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	56⅜	57·6	3299	37¼	7469	79·1
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	53	57·2	3153	34⅞	7061	80·7

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852–7).

The seed was sown on March 26th, the most forward plots were cut on August 11th, and carted on August 13th; and the remainder cut on August 17th, and carted on August 18th. The sowing was, therefore, rather late; but, with a hot and dry ripening period, the harvest was moderately early. There had been a good deal of rain in March; but, from that time up to harvest, very little. With the exception of June, which was cold, the spring and summer were generally warm, and the ripening period characterized by a very dry atmosphere. Notwithstanding the prevailing warmth and dryness of the growing periods, all the experimental plots gave very considerably more, of both corn and straw, than the average. Of corn there was generally more than in any other year of the 20, excepting 1863 and 1854; and with farmyard manure, by the use of which there is so much accumulation in the soil, more than in any year of the 20. The weight per bushel was also much above the average; throughout higher than in 1863, with few exceptions as high as, and in some cases higher than, in any other year. The experimental barley crop was, therefore, one of large produce of straw, indicating considerable luxuriance of growth; of exceptionally large produce of grain, which was of very exceptionally high quality. It is probable that, with the wet March, the plant found sufficient moisture in the soil for the requirements of its early growth; that, owing to the distribution of the comparatively small total fall during the rest of the season, it was sufficient under those preliminary conditions; that the low temperature of June prevented over luxuriance; that the cold nights, alternating with the hot days, of July, prevented premature ripening; and that the dry atmosphere during the final stages contributed to the high perfection of the grain.

These very favourable results in the experimental field are not inconsistent with the record of the barley crops in the country at large; for, though it was admitted that on light soils, and where sown late, the crop was very poor, it was equally admitted that, under more favourable conditions in these respects, it was very good.

Fourteenth Season, 1865.

After a rather wet September, but a very low aggregate rainfall during the first 9 months of the year, the concluding quarter of 1864 was also characterized by less rain than usual. The deficiency was very considerable in October and December, though there was rather an excess in November. As to temperature, the period was very variable, with a good deal of cold weather. There were occasionally very high winds; whilst the degree of humidity of the air was very unusually low in October, and somewhat low in November and December also. In January, 1865, there was a considerable, and in February a slight excess, but in March a deficiency of rain (including snow); though, throughout the quarter, the number of rainy days was small. Excepting the first half of January, the greater part of which was warm, the quarter was almost throughout unusually stormy and cold, with a good deal of snow; March in particular was generally very exceptionally cold and inclement. In April and June very little rain fell; whilst in May and July there was an excess, and in August a very great excess. In September, however, the fall was very exceptionally small. April, May, and the beginning of June, were much warmer than the average, but the remainder of June was variable, and, upon the whole, rather cold. The mean temperature of the quarter, and especially of April, was, however, the highest on record for that period of the year; and the air was pretty uniformly much drier than the average; the rain which fell being little distributed, coming for the most part in heavy showers. July, with an excess of rain, was also warmer than usual. The greater part of August was not only extremely wet, but rather colder than usual; whilst September was both the driest and hottest on record; completing, notwithstanding the comparatively low temperature of August, a hotter period of 6 months than any other known. In each month, too (excepting August, when it was very high), the degree of humidity of the air was generally very low.

The winter of 1864-5, though variable, was, therefore, upon the whole, very cold, stormy, and inclement; the early spring unusually cold and backward; but the remainder, and greater part, was very warm, with a dry atmosphere; though, towards the end, some heavy rains fell, and the combined conditions brought the crops very rapidly forward. June was also dry, hot at the beginning, though afterwards comparatively cool; July was hot, with a good deal of rain, but, upon the whole, a dry atmosphere; the greater part of August was cool and very wet, but the remainder, and September, very hot and dry, favouring the rapid completion of the hitherto much retarded harvest work. Thus, after a severe winter and late spring, the growing period was characterized by great heat, dryness of atmosphere, and a deficient amount and distribution of rain; the ripening period by an excess of rain, followed, however, by an eventually favourable, though late harvest time.

The wheat crop of the country was reported to be very variable; good on clays and land in good condition, but poor on light and badly farmed soils; in the aggregate about, or slightly under, average as to quantity; variable, and, upon the whole, only moderate in quality. Barley was said to be the best of the cereals, but inferior on light lands; oats the poorest crop for many years past.

The experimental wheat crop was, in quantity of corn, much below the average on the poorly manured, but considerably above it on the highly manured plots. The weight per bushel of dressed corn was, throughout, above the average; but the quantity of straw was almost throughout considerably below average, though proportionally the less so the higher the manuring. The results obtained in the experimental barley-field are shown in Table XV. (p. 46).

The wintry weather of March delayed all spring sowing, and the experimental barley was not put in until April 6th. On the other hand, the prevailing heat and drought of the spring and summer, brought grain crops early forward, and the whole of the

TABLE XV.—Quantity and Quality of Barley on Selected Plots.
Fourteenth Season, 1865.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	52¾	54·4	2923	25⅜	5769	102·7
1 O	Unmanured	18	53·9	1018	8⅛	1924	112·3
4 O	Mixed Mineral Manure ..	24⅜	54·0	1349	10	2464	121·0
1 A	200 lbs. Ammonia-salts ..	29⅞	53·8	1666	13	3127	114·0
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	46½	53·5	2549	22½	5075	100·9
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	48⅞	53·3	2684	24⅞	5469	96·4
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	48⅛	53·5	2648	22	5117	107·2

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852–7).

barley was cut on August 9th; but, owing to the wet weather which had then set in, it was not carted until August 18th. As might be expected from the characters of the season, and as was consistent with the results obtained in the experimental wheat field, there was throughout a considerable deficiency of total produce (corn and straw together), which was proportionally the greater the poorer the conditions as to manuring. There was, however, a very high proportion of corn to straw, the higher the poorer the manuring; and the weight per bushel of dressed corn was about the average. As to the actual amount of corn per acre, it was, without manure, with mineral manure alone, and with ammonia-salts alone, considerably below the average, but much nearer the average with the more complete manuring. The result is, then, that with a deficiency in total amount of rain, the very unequal distribution of that which fell, the very dry atmosphere, and the unusually high temperatures almost throughout the periods of growth, the conditions above ground were adverse to luxuriance, but very favourable to seeding tendency and maturation; and, where the conditions supplied within the soil were the most defective, the root-range would doubtless be the most restricted, and the plants would suffer the most; whereas, where the conditions supplied within the soil were liberal, a more extended root-range would render the plant less sensitive to the atmospheric heat and drought; and, hence, proportionally less failing in luxuriance.

The characters of both the experimental wheat and experimental barley-crops were, therefore, in the main accordant with those of the respective crops in the country at large. That is, the results in the experimental fields varied greatly according to the conditions of manuring; the crops suffering most where the conditions of manuring were the most defective, whilst it was on the light and badly farmed lands that the crops of the country suffered most. On the other hand, it was under the influence of liberal manuring that the quantity of corn was proportionally the highest in the experimental fields, and it was on the clays, and better farmed lands, that the crops were good in the country generally.

Fifteenth Season, 1866.

The very warm and dry weather of September, 1865, extended through the first week of October; and, although there were a few cold intervals, the temperatures of the three concluding months of the year ruled higher than the average; December, especially, being unusually warm. The period included, however, very great fluctuations in barometric pressure, and some extremely severe storms of wind; whilst in October a very excessive, in November a full, but in December a deficient, amount of rain fell. January and the first half of February (1866) were also unusually warm, though in January there was a heavy fall of snow, which, however, rapidly thawed, and the whole period was very wet. A cold and drier period then set in, and extended to the middle of March, checking the hitherto much too forward vegetation; and then, to the end of the quarter, the temperatures, though variable, ruled, upon the whole, very high, and there was a full amount of rain. The beginning of April was cold and rather wet, and the remainder considerably warmer and drier than the average. May was, throughout, unusually cold both day and night, and there was a deficiency of rain. June was changeable, but included a good deal of hot weather, which raised the mean temperature above the average, and during the month a considerable excess of rain fell. The beginning of July was cold and wet; then followed a week of hot and dry weather; but, from about the middle of the month to nearly the end of September, the weather was, with the exception of few and short intervals, generally cold, with a good deal of rain and wind in August, and an almost continuous and considerably excessive fall in September. October was, however, upon the whole, warmer and drier than usual. In June, July, August, September, and October, the degree of humidity of the air was generally high.

Thus, after a very wet and comparatively warm autumn, the winter was, until the middle of February, unusually warm, with a great deal of rain, inducing premature luxuriance of grass and winter-sown crops; then came a month of cold and dry weather, checking growth. The remainder of the spring was at first very variable, but May was unusually cold and dry. The early summer was changeable, but mostly warm, with a good deal of rain; and the ripening and harvest periods were almost continuously cold and rainy, with a moist atmosphere, but with occasional high and drying winds.

After the winter the wheat-plant was very forward, but was much checked by the prevailing, though not continuous, coldness and dryness of the spring. Recovering, and showing fair promise in early summer, it was again checked by the sunless weather, and in many cases laid and damaged by the wet maturing and harvest period. The harvest was protracted and late; and the crop was eventually pronounced to be below an average in quantity, though of fair quality. Barley and oats were said to be very variable; in some cases poor, in others much damaged; but, upon the whole, above average in quantity, and in some districts harvested in good condition, and of good quality.

The experimental wheat-crop was, under all conditions of manuring, below the average in quantity of corn; and, excepting under the highest manuring (when it was considerably above), below the average in quantity of straw also. The weight per bushel was, however, over average. The following results were obtained in the experimental barley-field:—

TABLE XVI.—Quantity and Quality of Barley on Selected Plots. Fifteenth Season, 1866.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	53⅛	54·9	3065	31½	6594	86·8
1 O	Unmanured	15⅞	51·1	858	9½	1928	80·1
4 O	Mixed Mineral Manure ..	24	52·7	1323	12⅞	2759	92·1
1 A	200 lbs. Ammonia-salts ..	27⅛	50·9	1474	15⅜	3200	85·4
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	47	54·7	2636	27⅜	5704	85·9
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	50⅞	55·4	2954	28¼	6117	93·4
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	48⅝	55·6	2834	27⅝	5929	91·6

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852–7).

The seed was not sown until April 2nd. The whole of the plots were cut on August 15th, 16th, and 17th; the earliest were carted on August 18th, but the remainder not until August 23rd and 24th. With, upon the whole, a dry and backward spring; a changeable, but mostly warm and wet, early summer;

but cold, wet, and windy ripening and harvest period, the result was considerably less than the average produce of both corn and straw without manure, and with defective manuring; but fully average quantity of corn, and not much less than average quantity of straw, with the more liberal artificial manuring. The farmyard manure, indeed, gave more than its average of both corn and straw; but, as will be seen further on, the produce on the farmyard manure plot increased very much during the later years of the experiment, so that the result must not be attributed exclusively to the season. The weight per bushel of dressed corn is seen to vary very considerably under the different conditions of manuring. Thus, without manure, and with ammonia-salts alone, the weight per bushel was considerably below the average under those conditions; whilst, with the more complex and more perfect artificial manures, and with the farmyard manure—that is with the more liberal soil-conditions—it was considerably above the average.

The smaller deficiency, if any, in total produce, and the higher quality, under high manuring, and the greater deficiency, and the poorer quality, under the poorer soil-conditions, are consistent with the results obtained in the experimental wheat-field, and also consistent with the character of great diversity given of the spring-sown crops of the country at large.

The season of 1866, with its late spring, its warm and wet early summer, but prevailing cold and wet later growing and ripening periods, gave considerably greater bulk of produce than 1865, with its also late spring, but warm and dry growing period. Though both seasons were unfavourable, they were essentially different in character. Yet they agree in this: that each was relatively less unfavourable with high than with poor manuring. The more perfect soil-conditions enabled the plant the better to withstand the heat and dryness in 1865, and the prevailing cold and wet of the growing and ripening period in 1866. That the quality of both wheat and barley was not worse in 1866, notwithstanding the cold and wet ripening period, was greatly due to the drying winds which alternated with the rains; but the much higher, indeed, the really high quality of the barley grown by liberal manuring, shows how much more vital power the plants growing under the more favourable soil-conditions possessed, and that in a certain degree those conditions compensated for the lacking favourable atmospheric conditions.

Sixteenth Season, 1867.

Though including some cold intervals, the concluding quarter of 1866 was generally warmer than the average, with somewhat less than the usual aggregate amount of rain, though a good deal fell within a short interval about the middle of November, causing floods, and hindering autumn sowing in some localities. In January, 1867, the fluctuations were very great; extreme cold and heavy falls of snow, alternating with rapid thaws, warm weather, heavy gales, and a good deal of rain. The last week of January, and almost the whole of February, were very unusually warm, with a large amount of rain at the beginning, and a moderate quantity over the rest of the period. March, again, was almost to the conclusion very cold and wintry, with a good deal of snow. Throughout the quarter there was a succession of gales of wind. Owing to the severe weather of March, the growth of winter-sown crops was checked; and owing partly to the wetness, and partly to the frost, the preparation of the land for spring-sowing was much retarded. April, and the beginning of May, were very unsettled; stormy, rainy, and changeable as to temperature; but, on the average, warmer than usual. Later in May, besides some very warm, there was a longer period of extremely cold weather, with a dry atmosphere, and frosty nights, much checking vegetation; though, during the month, there was rather more than the average fall of rain. June was comparatively dry, very changeable as to temperature, but on the average colder than usual. The cold weather continued throughout July and the beginning of August, and the period was generally sunless and cloudy, with an excess of rain in July, which fell very heavily towards the end of the month, and much laid, and in some cases inundated, the crops. The remainder of August, and September, were much finer, rather warmer than the average, though with rather more than the average fall of rain; which, however, was not much distributed, but fell for the most part in considerable quantities at a time.

Thus, the early winter was, upon the whole, warmer and drier than usual; then came intervals of severe frost, snow, and heavy gales, followed by several weeks of very warm weather, with a good deal of rain. The early spring was very wintry and stormy, and both growth and spring-sowing were retarded. The remainder was very changeable as to temperature; at first warmer, afterwards very unseasonably cold, and throughout frequently stormy and rainy. The rest of the growing, as well as the early ripening period, was changeable, though for the most part unseasonably cold, cloudy, and sunless, with a great deal, and some very heavy falls, of rain, which much laid the crops. The harvest-time, though late, and including some heavy rains, was, however, upon the whole, not unfavourable for the greater portion of the Midland, Southern, and Eastern districts.

With a wet autumn, a winter alternately very mild and very severe, a spring with alternations of extreme heat with cold, frost, and wet, and a summer with a good deal of sunless weather, with occasional violent storms of wind and rain, much laying the crops, were not conditions from which a productive harvest might be expected. Yet, both before and after the favourable change at harvest time, some writers in the 'Times' gave very sanguine views of the crops of the country at large. The records in the agricultural papers were, however, much less favourable; and the results obtained at Rothamsted led to the conclusion that the general wheat-crop would be not less than 20 per cent. below an average. Subsequent experience showed that this unfavourable estimate was only too well founded. Spring crops were almost everywhere sown late, especially on heavy lands. Barley was said to have suffered a good deal from the frosts of May, but at harvest the crop was reported to be but little under average in quantity, though variable in quality. Oats were considered to be over average.

The experimental wheat crop was very deficient in straw, and, upon the whole, more deficient in quantity of corn than in any year since 1853; though the quality of the grain was even over average. The following results were obtained in the experimental barley-field :—

TABLE XVII.—Quantity and Quality of Barley on Selected Plots. Sixteenth Season, 1867.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	45⅝	54·8	2614	27⅛	5652	86·1
1 O	Unmanured	17⅛	51·8	978	10¼	2124	85·3
4 O	Mixed Mineral Manure ..	20⅞	53·6	1180	12	2526	87·7
1 A	200 lbs. Ammonia-salts ..	30⅝	51·3	1686	17¼	3611	87·6
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	43⅞	54·3	2454	25½	5304	86·1
4 A A	Mixed Mineral Manure, and 200 lbs. (1) Ammonia-salts	45	54·6	2573	28⅜	5753	80·9
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	42⅝	54·8	2411	24¼	5121	89·0

(1) 400 lbs. the first 6 years (1852–7). (2) 2000 lbs. the first 6 years (1852-7).

Owing to the alternate wet and frost, and the consequent unworkable condition of the land, the experimental barley was again sown late, not being put in until April 5. The earlier plots were cut on August 20 and 21, the later not until August

27 and 28, and the whole were carted on August 31. The earlier and better crops, those grown by manures containing nitrogen and superphosphate, and by farmyard manure, were the most laid. Notwithstanding this, owing to the improved weather at the final ripening, and harvest time, it was just these crops that gave a rather better than average weight per bushel of corn, whilst the poorer and more backward crops gave lower than the average weight per bushel. The quantity of both corn and straw was throughout lower than the average, and the deficiency was proportionally the greater the greater the relative deficiency of available nitrogen within the soil; that is to say, without manure, and with purely mineral manure. The proportion of corn to straw was generally not far from the average, and, under some of the best conditions of manuring, somewhat over the average. Upon the whole, therefore, the experimental barley crop was deficient in quantity, but of full average quality. The deficiency in the spring-sown crop was, however, much less than that of the experimental wheat; and less, perhaps, than might have been expected considering the late sowing, the alternations of forcing and checking conditions of weather during the earlier stages, and the sunless character of the later periods of growth. The result is, at the same time, consistent with that recorded of the barley-crop of the country, which, according to the more reliable authorities, suffered considerably less than wheat; it is also consistent in showing relatively less deficiency the better the soil-conditions.

Seventeenth Season, 1868.

October, 1867, was very variable as to temperature, upon the whole colder than usual, with comparatively little rain, but occasional high winds. There was very unusually little rain in November, and the weather was for the most part clear but cold, and very favourable for working the land and sowing. December was characterised by great and rapid variations of temperature and barometric pressure, some extremely heavy gales, sometimes frost, snow, and sleet, at others very warm weather; in the aggregate there was a full amount of rain, and throughout the month agricultural operations were much impeded. The first eleven days of January, 1868, were very cold; but from that time to the end of the quarter (indeed to the end of the summer), the weather was unusually warm. There was a considerable excess of rain, and there were several gales of wind, in January; but there were only moderate amounts of rain in February and March. In these months vegetation became very forward, and the weather was generally favourable for working the land and for spring sowing. April, May, and June, again, were all considerably warmer than the average. The average temperature of April had however frequently, and that of each of the other months occasionally, been exceeded in the corresponding months of other years; but the average temperature of the three months together had only once been exceeded in any corresponding three months for 98 years (the period for which records are available), namely, in 1865, when, though April was hotter, May and June were not quite so hot as in 1868; and the average temperature of the whole period, from the middle of January to the end of June, was only exceeded in 1822. Concurrently with this long-continued warm weather, there was, as already said, a great excess of rain in January, and only moderate amounts in February and March; there was a small excess in April, a deficiency in May, and a very great deficiency in June. Temperatures in excess of the average also prevailed almost continuously throughout the succeeding quarter, namely, to the end of September. July, in particular, was very excessively warm, with at the same time a continued great deficiency of rain; August was also warmer than the average, but with a good deal of rain; and September more in excess as to temperature than August, with a deficiency of rain. In no year of the previous 98 had the temperature so far exceeded the average in so long a corresponding period as that from the middle of January to the end of September of this year, 1868. The total rainfall of the nine months was not much below the average; but the amount which fell was very excessive in January, and excessive also in April and in August, whilst it was deficient in each of the other months of the period, and very greatly so during the three consecutive months of greatest heat, namely May, June, and July. The degree of humidity of the atmosphere was also lower than the average in each of the nine months from January to September inclusive, greatly so in June, very greatly so in July, and considerably in August and September.

The characters of this extraordinary season may be briefly summarised as follows:—After a favourable autumn seed-time, the first half of the winter was very variable, including some very warm, but more stormy, wet, snowy and frosty weather. From that time to after harvest, the temperature was almost always above the average, and very greatly so in the summer months of June and July; whilst, after a favourable spring seed-time, there was a sufficiency of rain in April to give a fair start to early-sown crops; but, from that time until the harvest was nearly over, throughout the Midland, Southern, and Eastern districts of the country, the excessive temperatures were accompanied by a drought of unusual severity, both as regards the length of its duration, and the great amount of the deficiency of rain, with at the same time a very dry atmosphere.

With the favourable autumn seed-time, the area under wheat was over average. In the spring the plant was generally good, the harvest was very early, and finally the crop was reported to be considerably over average in both quantity and quality on good and well farmed soils; on light and poorly farmed land, on the other hand, the crop suffered much from the heat and drought. Still, the aggregate wheat crop of the country was supposed to be about 20 per cent. over average in quantity, and of over average quality. Naturally, spring-sown crops suffered much more from the heat and drought than wheat. Barley was, however, said to yield well, and be of good quality, on deep and well-farmed lands, and when sown early, but to be very deficient when sown late, or on shallow soils; and to be so on many of the usually good barley lands. Oats suffered more than barley, and were almost universally reported to be under average, and in many cases a complete failure.

The produce in the experimental wheat field was, under all conditions of manuring, over average in quantity, but proportionally much more so with high than with low manuring. The weight per bushel of dressed corn ranged from 3 to 5 lbs. over the average. The quantity of straw was considerably below the average with low manuring, but average, or over average, with high manuring. The proportion of corn to straw was also generally over average, but proportionally the less so the higher the manuring and the greater the bulk of the crop. The following results were obtained in the experimental barley-field:—

TABLE XVIII.—Quantity and Quality of Barley on Selected Plots. Seventeenth Season, 1868.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	43⅝	57·1	2539	24½	5281	92·6
1 O	Unmanured	15⅝	54·3	873	11⅝	2173	67·2
4 O	Mixed Mineral Manure ..	17⅝	55·3	998	10⅛	2126	88·5
1 A	200 lbs. Ammonia-salts ..	20⅜	53·3	1136	12¼	2507	82·9
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	34⅝	55·6	1978	20⅞	4311	84·8
4 A A	Mixed Mineral Manure, and 275 lbs. Nitrate Soda (1) ..	45⅜	56·0	2586	25⅝	5454	90·2
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	36¼	55·4	2051	21⅛	4414	86·8

(1) 400 lbs. Ammonia-salts the first 6 years (1852–7), 200 lbs. the next 10 years (1858–67); 275 lbs. Nitrate Soda, 1868, and since.

(2) 2000 lbs. the first 6 years (1852–7).

Unfortunately, the seed was not put in until March 20; and with, excepting in April, a great deficiency of rain from that time until harvest, and, at the same time, unusually high temperatures and dry atmosphere, the crop was, for the locality, very early cut, namely, on July 31, and it was carted on August 5. The deficiency of both corn and straw is throughout very considerable, but proportionally the greater the more defective the manuring. Thus, compared with the average of the twenty years in each case, the deficiency of total produce, corn and straw together, was with farmyard manure only about one-tenth, with mixed mineral manure and ammonia-salts (4 A), and with mixed mineral manure and rape-cake, about one-fourth, but with mineral manure alone, or ammonia-salts alone, about one-third. Further, in these cases of the more defective manuring, and the more deficient total crop, the proportion of corn to straw is below the average, whilst, with the nitrogenous and mineral manure together, as well as with farmyard manure, the proportion of corn to straw is rather higher than the average. Deficient as was the quantity, the quality was, however, in all cases high; and the higher the more liberal the conditions of manuring. Thus, the weight per bushel was between 55 and 56 lbs. with the mixed mineral manure and ammonia-salts, and with the mixed mineral manure and rape-cake, and was over 57 lbs. with farmyard manure.

It will be borne in mind that, during the first six years of the twenty (1852-1857), plot 4 A A had annually twice as much ammonia-salts as 4 A, but that, during the next ten years (1858-1867), only the same quantity of ammonia-salts was applied as on 4 A, namely, 200 lbs. per acre per annum; and reference to the tables will show that there has continued to be some excess of produce on 4 A A, as compared with 4 A, due to the unexhausted residue from the excessive supply during the first six years. For the year 1868, and subsequently, however, an amount of nitrate of soda, containing the same quantity of nitrogen, has annually been substituted on plot 4 A A for the 200 lbs. of ammonia-salts applied during the previous ten years; and it will be seen that, in this year of drought, the plot with the nitrate gives nearly 11 bushels more corn, and about 5 cwts. more straw, than the plot with an equivalent quantity of nitrogen as ammonia-salts. This amount of excess is much greater than has been obtained in any succeeding year hitherto; though in 1870, which was also a year of drought, the excess of produce with the nitrate was again very considerable.

In a paper in the 'Journal of the Royal Agricultural Society of England,'* we showed that the soil of the plot in the experimental wheat-field which had then been manured with 14 tons of farmyard manure per acre per annum for twenty-five years in succession, owing to its vast accumulation of organic matter, and greater degree of disintegration, porosity, and power of absorption, retained, near the surface, very much more water than that of either the closely-adjoining unmanured, or an artificially manured plot in the same field.

In the same paper we recorded the fact, that a plot of permanent meadow-land which received annually mixed mineral manure, and a given amount of nitrogen as ammonia-salts, yielded in the season of drought of 1870, 23 cwts. of hay less than its average; whilst, another plot, receiving annually the same mineral manures, and the same amount of nitrogen, but in the form of nitrate of soda instead of ammonia-salts, yielded, in the same season of drought, only 1¼ cwt. of hay less than its average amount, and about 26¾ cwts. more than the plot manured with the same mineral manure and the same amount of nitrogen as ammonia-salts.

This result was assumed to be connected with the difference in the character of the two nitrogenous manures (ammonia-salts and nitrate of soda), in regard to their reactions upon the soil, and the consequent degree of rapidity and range of distribution of them, or their products of decomposition, within it;—the nitrate, or its products of decomposition, becoming much more rapidly distributed, and washed into the subsoil, whither the roots follow it. On examination it was found —that certain plants of the mixed herbage, having roots of a characteristically downward tendency, were much more prevalent on the plot manured with nitrate of soda, than on that manured with ammonia-salts; that the subsoil of the nitrated plot was disintegrated and permeated by roots to a much greater depth; and that, accordingly, the lower layers of the subsoil had been pumped much drier by the action of roots, than the corresponding layers of the plot manured with ammonia-salts.

These very interesting and significant facts point to the explanation of the much less prejudicial influence of the drought of 1868 on the experimental barley-crops grown by farmyard manure, and by mineral manure and nitrate of soda, than on those grown by mineral manure and ammonia-salts. In the case of the farmyard-manure plot, the result was probably due to the great amount of moisture taken up, and retained, by the upper layers of the soil, from the winter and early-spring rains. In that of the nitrated plot it was, it is true, the first year of the application;

* Vol. vii.—s.s. Part I.—"Effects of the Drought of 1870 on some of the Experimental Crops at Rothamsted."

but, with the fair amount of rain in March, and the full amount in April, it is still probable that there would be a considerable distribution of the manure, and, accordingly, an increased disintegration, and porosity of the subsoil, and retention of moisture by it; the combined conditions leading to a correspondingly greater distribution of the roots in the lower layers, by virtue of which the plants would obtain possession of a greater range of soil, and an increased supply of moisture within it. In the one case, therefore, it was the resources of moisture in the upper layers of the soil, and in the other those in the lower layers, that rendered the growing crop more independent of the supplies from external sources.

In conclusion, the difference of effect of the excessive summer heat and drought on winter and spring-sown crops, and on crops grown on deep and on shallow soils, was very striking. Thus, the experimental wheat-crop indicated a produce about 20 per cent. over the average, and the wheat-crop of the country at large was extremely good on good soils, though very poor on poor soils, yet was supposed to yield in the aggregate 20 per cent. over an average. The rather late-sown experimental barley, on the other hand, gave a produce from one-tenth to one-third below the average, according to the manure employed; and the barley-crop of the country was good when sown early on deep soils, and very deficient when sown late on shallow soils, but gave in the aggregate a considerably deficient crop. The great protection against the injurious effects of summer drought, which the early sowing of spring-crops gives, by enabling the plant to obtain possession of a more extended root-range, was thus, in this season, strikingly illustrated.

Eighteenth Season, 1869.

The extraordinarily warm period of nearly nine months duration ended with September, 1868. October and November were throughout, with very few exceptions, colder than usual, both day and night; whilst in October there was a deficiency of rain, and in November a very great deficiency. December, on the other hand, was almost throughout very much warmer than the average, with a very great excess of rain, some violent gales of wind, very variable, but, upon the whole, very low barometric pressures, and high degree of humidity of the atmosphere. The average temperature of December had, indeed, been exceeded only twice during the preceding ninety-eight years; namely, in 1806 and 1852. With the exception of a week after the middle of January (1869), the very warm period continued until the end of February, completing three winter months of average temperature about 6 degrees higher than the average of ninety-eight years. There was, again, considerable excess of rain in January, and a slight excess in February. March, on the contrary, was several degrees colder than the average, with about, or less than, the average amount of rain. Early in April warm weather set in, and lasted till nearly the end of the month, the temperature during this period being several degrees higher than the average, whilst the fall of rain was generally under the average. May and June were, with few exceptions, of short duration, very much colder than the average. Towards the end of May the cold was very extreme for the season, and the greater part of June was very unusually cold, both day and night; and in May there was a considerable excess, though in June a deficiency, of rain. Early in July there was again a change to warm weather, which lasted till the end of the month, during which there was very little rain. The first three weeks of August were very unseasonably cold and showery, though the total amount of rain was comparatively small; but the concluding week of the month was very bright and hot. Then came a short period of cold weather, but the remainder of September was warm but stormy, with a good deal of rain. In April, May, and June, the degree of humidity of the air ranged high, especially in May; in July it was about the average, but in August and September it was below it.

To sum up the characters of the season: The heat and drought of the spring and summer of 1868 were followed by a warm and dry September, but cold and dry October and November, providing a good autumn seed-time. The three winter months were very warm, and, December and January especially, very wet, bringing autumn-sown crops very rapidly forward, and providing an unusual amount of winter grazing, which greatly compensated for the previous deficiency. But, owing to the condition of the land, spring sowing was retarded. The weather in March was dry and cold, much checking vegetation; which, however, recovered rapidly under the influence of very warm, though somewhat dry, weather in April; but the remainder of the spring was very cold, and also wet; June, again, for the most part cold; July warm, most of August cold, the conclusion, and September, hot; whilst the summer was comparatively dry, though the harvest-time somewhat unsettled.

With a season characterised by alternate periods of forcing and checking weather, with more of the latter than of the former during the time of most active growth, and with a changeable ripening and harvest period, favourable or unfavourable for the crops according to their forwardness at the time, the reports of the crops of the country generally were very conflicting. The wheat-crop, though very variable, was reported to be, in the aggregate, somewhat below an average, both in quantity and quality. The barley-crop was also very variable, but, perhaps, upon the whole rather better than wheat. Oats were more uniformly bad.

In accordance with the characters of the crop of the country, the experimental wheat-crop was very variable; much below the average under most conditions of manuring, but above it under others; and particularly so with farmyard manure, and the mixture of mineral manure and nitrate of soda—a point to which further reference will be made presently. The results in the experimental barley-field were as follows:—

TABLE XIX.—Quantity and Quality of Barley on Selected Plots. Eighteenth Season, 1869.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	46 7/8	56·4	2746	28 5/8	5959	85·5
1 O	Unmanured	15 1/8	52·4	840	11	2075	68·0
4 O	Mixed Mineral Manure ..	22 1/4	54·6	1286	12 7/8	2729	89·2
1 A	200 lbs. Ammonia-salts ..	27 7/8	52·4	1599	18 1/4	3640	78·4
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	49 1/4	57·4	2848	34 3/8	6701	73·9
4 A A	Mixed Mineral Manure, and 275 lbs. Nitrate Soda (1)	49 7/8	57·1	2929	38 1/8	7194	68·7
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	52 1/8	57·4	3065	35 1/8	7001	77·9

(1) 400 lbs. Ammonia-salts the first 6 years (1852–7), 200 lbs. the next 10 years (1858–67); 275 lbs. Nitrate Soda, 1868, and since.
(2) 2000 lbs. the first 6 years (1852–7).

The seed was sown on March 13th; the earlier crops were cut on August 5th, and carted on August 16th; and the later cut on August 19th, and carted on August 25th. Between cutting and carting there was some cold and showery weather; but notwithstanding the later crops (those not manured with superphosphate) had the benefit of much hotter and drier weather before being carried, than the earlier (which were manured with superphosphate), the latter gave by far the higher weight per bushel; considerably higher indeed than the average. Unlike the wheat, the experimental barley gave, under liberal manuring, very generally more, both corn and straw, than the average; but without manure, with mineral manure alone, and with ammonia-salts alone, the produce, more especially of corn, was considerably below the average. The crop was, upon the whole, bulky, being heavy in straw; so that even where the produce of corn was more than the average, the proportion of corn to straw was less than the average.

After an unusually wet winter, the soil and subsoil would, doubtless, retain a good deal of moisture at seed-time, and, although March was cold and dry, April was warm and forcing, May was cold and wet, and June also cold; so that the characters of the season were obviously such as would tend to bulk, rather than to seeding tendency. In the case of the barley such was the result, but in that of the wheat the straw was proportionally more deficient than the corn. Again, with barley, there was more than average produce, both corn and straw, with mixed mineral manure and a given amount of nitrogen, whether supplied as ammonia-salts or as nitrate of soda; whereas, with wheat, there was a deficiency of both corn and straw with mineral manure and ammonia-salts, but an excess of both with the same mineral manure and the same amount of nitrogen supplied as nitrate of soda. It will be useful to try and trace the explanation of these differences.

It will be remembered that, in the season of drought of 1868, the experimental wheat-field gave much more, whilst the experimental barley-field gave much less, than average produce. In 1869, however, after a very wet winter, and, for the most part, cold weather at the periods of most active growth, the experimental wheat-field gave generally much less, whilst the barley-field yielded considerably more than the average. Doubtless, the advantage which the wheat had over the barley in the year of drought was due to its having obtained possession of a considerable range of soil before the drought commenced, and being thereby rendered less dependent than the spring-sown barley on the rain actually falling during the periods of active growth. The failure of the wheat as compared with the barley in 1869, after the very wet winter, was probably due, in great measure, to the washing out and loss by drainage of the nitrogen of the ammonia-salts sown in its case in the autumn; whereas, for the barley, the manures were not sown until the spring. A corroboration of this view is the fact that, though there was so considerable a deficiency in the produce of wheat with mixed mineral manure and a given amount of nitrogen supplied in the form of ammonia-salts sown in the autumn, there was no deficiency, but an excess of produce, of that crop, where the same mineral manures and the same amount of nitrogen were supplied, but the latter in the form of nitrate of soda, and applied no before the winter rains, but in the spring.

In a paper already referred to,* we have pointed out how very serious may be the loss of nitrogen by drainage, when ammonia-salts or nitrates are liberally applied in the autumn, and there is much wet weather during the winter; or even when sown in the spring, if very heavy falls of rain should follow. Not only, however, is the rain of the spring and summer generally less continuous than that of the winter, but, as the season advances, the soil itself is usually in a drier state, there is more evaporation from it, and considerably more also from vegetation, tending to lessen the proportion of the rain passing below the reach of the roots, and carrying with it fertilizing matters. For important data relating to this subject we would refer to a paper by Professor Voelcker.† Some of the results he records we shall quote further on (Section IV. p. 138); but it may be useful to give here a single paragraph from our own paper above referred to.

"Fortunately, some of the most important mineral constituents of soils and manures are, in the case of the heavier soils at any rate, almost wholly retained by them within the range of the roots of our crops. Nitrogen, whether supplied in the form of ammonia-salts or nitrates is, however, much less completely so retained; being, in whichever state supplied, carried off in greater or less quantity in the drainage-water, chiefly in the form of nitrates. According to results obtained independently by Professor Frankland and Professor Voelcker, on the analysis of drainage-water from the experimental wheat-field at Rothamsted, that collected during the winter, from land manured in the autumn by an amount of ammonia-salts supplying 82 lbs. of nitrogen per acre, may contain from 2·5 to 3 parts, or even more, of nitrogen, as nitrates and nitrites, per 100,000 parts of water. Assuming that only 2·5 parts of nitrogen were so carried beyond the reach of roots for every 100,000 parts of water passing downwards, there would still be, for every inch of rain so passing, a loss per acre of between 5 and 6 lbs. of nitrogen, supplied in manure at a cost of not much less than 1*s.* per lb."

Now, in December, January, and February, 1868-9, about 10·5 inches of rain fell, being about 4·5 inches more than the average; and although data are at present wanting for anything like an accurate estimate of what proportion of this large amount

* 'Journal of the Royal Agricultural Society of England,' vol. vii.—s.s. Part I.

† "On the Productive Powers of soils in relation to the loss of Plant-Food by Drainage." By Professor Voelcker, Ph.D., F.R.S. ('Jour. Chem. Soc. Lond.,' June, 1871.)

of rain would pass away by drainage,* it may at any rate be concluded that several inches would do so. It can hardly be wondered at, therefore, that, in the case of the wheat, the plots receiving nitrogen as ammonia-salts in the autumn were much less productive than usual, and also, in a much greater degree than usual, deficient compared with the plot receiving its nitrogen as nitrate of soda applied in the spring.† It is intelligible, too,

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* See evidence on this point in the paper in the 'Journal of the Royal Agricultural Society of England,' before referred to. Vol. vii.—s.s. Part I.

† During the early years of the comparative trials, a given amount of nitrogen, applied as ammonia-salts in the autumn, gave more produce of wheat, both corn and straw, than an equal quantity applied in the spring as nitrate of soda; but during the last 12 or 14 years the nitrate of soda, applied in the spring, has given more produce than the ammonia-salts applied in the autumn.

The years in which the nitrate showed specially great superiority over the ammonia-salts, due rather to deficiency of produce by the latter, than to any considerable excess over the average by the former, were 1860, 1867, 1869, and 1871. In 1860 the produce by ammonia-salts was very much less than the average, and by the nitrate slightly under the average, though much above the ammonia-salts; and the records show that there had been an excess of rain in November, December, and January, and again in March, April, May, and June. In 1867 there was a greater deficiency of total produce by the ammonia-salts than in any other year, a small deficiency even by the nitrate, and very great deficiency by the ammonia-salts compared with the nitrate; and there had been a greater or less excess of rain in almost every month from seed-time to harvest, namely, in November, December, January, February, March, April, May, and July. In 1869 there was a considerable deficiency by the ammonia-salts, but less than in 1860 or 1867; and by the nitrate a small excess over its average, and a great excess over the ammonia-salts; and there had been a considerable deficiency of rain in November, but a very considerable excess in December, January, and February, a slight excess in April, and a greater excess in May, but very dry weather afterwards until harvest. Lastly, in 1871, there was a very considerable deficiency by the ammonia-salts, a slight excess by the nitrate, and very great excess by it as compared with the ammonia-salts; there was an excess of rain in December and February, and a great excess in April, June, and July.

There was also considerable excess by the nitrate compared with the ammonia-salts in 1862, in 1866, and in 1868. But in these cases, especially in 1862 and 1868, the result was, for the most part, due to over average produce by the nitrate, and but little, if at all, to under average by the ammonia-salts. Accordingly, in 1861–2, after a considerable deficiency of rain in the three preceding months, there was a considerable excess in November, but again a deficiency in December, January, and February, and then a considerable excess in March, April, May, and June—that is after the nitrate had been applied, but after active vegetation had commenced. Again, in 1868, with a deficiency of rain in each of the four preceding months there was a slight excess in December, considerable excess in January, slight excess in February, March, and April, but very great deficiency afterwards until harvest.

These examples, though differing much from one another in many points, nevertheless sufficiently clearly point to the conclusion that, in the first series of years enumerated, the considerable difference between the amount of produce by the ammonia-salts applied in the autumn, and the nitrate of soda applied in the spring, was due to deficient produce by the former resulting from a washing out of its nitrogen by the winter rains; whilst, in the other instances, it was due to the greater effectiveness of the nitrate under the influence of the conditions of the season after the commencement of active growth, which were widely different in the two cases more specially noticed; giving, in 1862, with a comparatively wet that the barley, the whole of the manures for which were applied in the spring, should, equally with the wheat-plot which received its nitrogen in the spring, give more than average total produce, and especially an excess of straw.

The very different results obtained with winter-sown and spring-sown crops, in the strikingly contrasted seasons of 1868 and 1869, thus illustrate very instructively the extremely varying effects of some of our most active manures, according to the time of their application, and to the characters of the season. Moreover, with the explanations given, it becomes the more intelligible that, in certain seasons, the accounts of the growing crops should be very conflicting for soils of different characters and in different conditions as to manuring. A consideration of the results obtained in the next season, 1870, which was one of even more prolonged drought than that of 1868, will be confirmatory of the explanations given of the results of that year, and will afford further opportunity for usefully directing attention to the points involved.

Nineteenth Season, 1870.

Until the middle of October the autumn of 1869 was for the most part warm, with a good deal of rain. From that time until the end of the year the weather, though including some rapid fluctuations, some very warm days, and a warm period of more than a week in the middle of December, was otherwise very cold and inclement, and especially wintry towards the end of October; there were numerous gales throughout the quarter; but there was less rain than usual in October, about the average in November, and a considerable excess in December. The falls were heavy and continuous at the end of November, and again in the middle of December; and the drains in the experimental wheat-field ran frequently from November 28th, 1869, to January 1st, 1870. The first three months of 1870 were characterised by frequent alternations of warm and very cold weather—the colder periods being, however, much the longer, and sometimes very severe; snow was very frequent, but the rain-gauge indicated a deficient fall in January, in some localities a deficiency in February, but

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and cold spring and early summer, a greater excess of straw, and in 1868, with very hot and dry weather during the most active period of growth, a greater excess of corn.

It will be understood that the above remarks are not supposed to give anything like a complete description of the characters and effects of the seasons referred to, but are only intended to illustrate the difference of effect of a given amount of nitrogen supplied as ammonia-salts in the autumn, and as nitrate of soda in the spring, dependent, in great measure, on the different degree of liability to loss by drainage in the two cases.

a very heavy fall early in the month, and an excess in March. From early in April to near the end of the month the weather was very warm and dry; then followed about a fortnight of cold and cloudy weather, from which time until nearly the end of June it was again very warm, sunny, and dry—the three months together being not only warmer than the average, but very unusually deficient in rain. The day-temperatures especially were high, though the night-temperatures were in April and May low, but in June high. The end of June and the beginning of July were cold and variable, but the remainder—indeed, nearly the whole of July, as well as the first half of August—were very warm. Then, to the end of September, a period of about six weeks, the temperatures were pretty uniformly below the average, though the weather continued fine. Thus, the period of drought, which had commenced with April, continued to nearly the end of August, and even in September there was less than the average fall of rain. The great deficiency of rain throughout five consecutive months was, moreover, accompanied by great dryness of atmosphere—the degree of humidity of the air being in April very unusually low, and in May, June, July, and August, also considerably below the average.

The autumn of 1869, though, as the details show, frequently cold, boisterous, and inclement, was, upon the whole, not unfavourable for getting in the seed. The winter, though changeable, included a great deal of very cold weather. In the early spring both field-work and vegetation were very backward, and at the end of April grass-land was very brown and bare. From the beginning of April until harvest the weather was, with few exceptions, of short duration, warmer than usual, with a great deficiency of rain and a very dry atmosphere.

The combined heat and drought were even more extreme during the months of May, June, and July, 1868, than during the corresponding months in 1870; but in the latter year the deficiency of rain commenced a month earlier, and continued later than in 1868. Hence, the grass crops suffered the more, indeed very excessively, in 1870; and, for a parallel, we must go back as far as 1844. As in the two preceding years (1868 and 1869), the reports of the cereal crops of the country were very variable, but for very opposite reasons in the years of heat and drought, 1868 and 1870, as compared with 1869. In 1870, the year now under consideration, the wheat plant suffered much before the active growing time began—in some cases from wire-worm, and in others from frosts; in not a few instances it was ploughed up and spring-corn sown; whilst, over large areas, the remaining plant was said to be very thin on the ground, and there was very much more than usual difference in the character of the crops in adjoining fields. Still, the best wheat lands were said to carry, though not a bulky, yet a very good yielding crop, and to give grain of very high weight per bushel. Estimates of the aggregate yield for the most part put it, if not under, at scarcely over an average; but the annual report from Rothamsted (though admitting that the country had probably produced some of the lightest as well as some of the best crops ever known) laid it at rather over average. Barley was also very variable. The seed had for the most part been got in well, and, where sown early and in deep soils, was good; but when sown late, and in light soils, it had suffered very much from the drought. Oats were also generally well got in; but, besides injury from wire-worm, they had suffered from the heat and drought more than either wheat or barley, and gave, upon the whole, a very light crop throughout Midland, Eastern, and Southern districts.

The experimental wheat-field gave, under all conditions of manuring, considerably less than the average produce of straw; but, without manure, and with farmyard-manure, about the average, and with liberal artificial manuring (mineral manure and ammonia-salts or nitrate of soda) considerably more than the average quantity of corn. Under all conditions the weight per bushel was much over the average; in fact, generally, though not uniformly, as high as in any preceding year. The following results were obtained in the experimental barley-field:—

TABLE XX.—Quantity and Quality of Barley on Selected Plots.
Nineteenth Season, 1870.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity.	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs	
7	14 Tons Farmyard Manure	47½	57·1	2734	19¾	4950	123·4
1 O	Unmanured	13½	52·9	751	6⅝	1489	101·8
4 O	Mixed Mineral Manure ..	18½	55·6	1053	9⅜	2101	100·5
1 A	200 lbs. Ammonia-salts ..	27¾	54·6	1539	12½	2945	109·4
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	38	57·1	2197	18⅝	4287	105·1
4 A A	Mixed Mineral Manure, and 275 lbs. Nitrate Soda (1)	44½	57·1	2571	18¼	4621	125·4
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	43¾	58·0	2569	20⅜	4857	112·3

(1) 400 lbs. Ammonia-salts the first 6 years (1852–7), 200 lbs. the next 10 years (1858–67); 275 lbs. Nitrate Soda, 1868, and since.

(2) 2000 lbs. the first 6 years (1852–7).

The seed was sown on March 15; the usually earliest plots were cut on July 27, and carted on August 5; and the remainder were cut on August 8, and carted on August 12. With a very unusually deficient rain-fall from the date of sowing until harvest, and also a great deal of hot weather, the amount of total produce (corn and straw together) was, as might be expected, very much below the average; and the deficiency of straw was throughout greater than that of corn. Without manure, and with mineral manure alone, the produce of corn was only two-thirds the average, and that of straw even less, especially without manure. In most other cases the produce of straw was only about two-thirds the average, whilst that of corn ranged from five-sixths of the average to nearly average. As in 1868, the deficiency of corn was much less with farmyard-manure, and with mineral manure and nitrate of soda, than with mineral manure and ammonia-salts. In 1870 it was also considerably less with mineral manure and rape-cake. The proportion of corn to straw was, under all conditions of manuring, very high, and under some higher than in any other year of the twenty. It was the highest, indeed very unusually high, with farmyard-manure, with rape-cake, and with mixed mineral manure and nitrate of soda. The only years approaching 1870 in proportion of corn to straw were 1857 and 1865, both of which had, however, considerably the advantage in actual quantity of corn per acre. The quality of the grain, as indicated by the weight per bushel, was throughout considerably higher than the average, and under some of the most liberal conditions of manuring it was as high as, or higher than, in any other year.

Thus, with a drought of extraordinary severity, extending through the whole period of active growth and ripening, accompanied for the most part with higher temperatures than usual, and a very dry atmosphere, the experimental wheat-field gave considerably less straw, but with high artificial manuring considerably more corn, than the average, and grain of very high quality. The spring-sown barley, on the other hand, gave a crop deficient in both straw and corn; very deficient in straw, and very deficient in corn also with defective manuring, though much less so with high manuring; and, like the wheat, it gave grain of very high quality. The greater power of the winter-sown crop to withstand spring and summer drought and heat, provided the subsoil be moderately retentive, is here again illustrated.

Compared with 1868, which was considerably hotter during May, June, and July, but not deficient in rain in April or August as well as the intermediate months as was 1870, the experimental wheat-field gave, in 1870, very much less straw than in 1868, but under liberal artificial manuring about, or nearly, as much corn. The experimental barley-field, on the other hand, gave under some conditions of manuring more, but, upon the whole, less straw, though, under high manuring, more corn in 1870 than in 1868. In fact, owing to the greater heat, the soil was probably deprived of its moisture to a greater degree by the shorter drought of 1868 than by the longer one of 1870, and hence the less productiveness of the spring-sown crop in the former than in the latter year.

When speaking of the crop of 1868, attention was called to the fact that the farmyard-manure plot, and the one receiving mixed mineral manure and nitrate of soda, suffered much less from the drought than that receiving mixed mineral manure and ammonia salts. In 1870 the general character of the results was, as already intimated, very similar. Under each of the conditions mentioned, the deficiency of straw was, it is true, considerably greater in 1870 than in 1868; due, doubtless, to the much less rain in April; but the produce of corn was, with farmyard-manure considerably higher than, and with mixed mineral manure and nitrate of soda nearly as high as, in 1868; indeed, with farmyard-manure, it was very nearly average, and with the nitrate, as in 1868, very much higher than by mixed mineral manure and the same amount of nitrogen supplied as ammonia salts—though, as the produce by the ammonia salts was not so defective in 1870 as in 1868, neither was the excess by the nitrate so great as then. There can be little doubt that, the greater porosity of the soil, and the consequently greater power of absorption and retention of moisture near the surface, where the dung was applied, and the greater disintegration and porosity of the subsoil, and the more extended distribution of the manure and of the roots within it, where the nitrate was used, had again enabled the growing crops the better to withstand the heat and drought.

To sum up: The extraordinarily prolonged season of drought of 1870, though yielding, as might be expected, small amounts of total produce (corn and straw together), of both wheat and barley, but especially of the spring-sown crop, was remarkable for giving, of wheat grain even an excess, and of barley grain much less deficiency, the higher the manuring; much less deficiency with farmyard-manure, and with nitrate of soda, than with ammonia-salts; and, with both crops, very high proportion of corn to straw, and very high weight per bushel of corn.

Twentieth Season, 1871.

In October, 1870, the changes of temperature were very frequent, giving, however, about the average for the month; and there was a slight excess of rain. The first 19 days of November were for the most part cold, the remainder warm, but the average for the month was low, and there was a considerable deficiency of rain. There were about 10 days of very warm weather in the middle of December, but the beginning and end of the month were cold; the latter extremely so, with a good deal of snow and cold wind; the average for the month was 5 or 6 degrees below the average for 99 years; and the rain, and melted snow, indicated a considerable excess of fall. January, 1871, with the exception of a few days in the middle of the month, was cold; and at the beginning, and for nearly a fortnight at the end, the weather was extremely severe. From early in February, until the middle of March, the weather was very mild, and thence to the end of the month the temperatures were very variable. There was a full amount of rain (or snow) in January, but a deficiency in both February and March; though the melting of the snows of January, succeeded by frequent rains early in February, caused floods in many parts. April, May, and June were, with the exception of the latter half of April, which was warm with a good deal of south-west wind and rain, unusually cold, with a great deal of east or north wind, or some compound of the two; and there was an excess of rain in April and June, but a deficiency in May; June, especially, being very unseasonably cold and wet. July, excepting about a week after the middle of the month, was cold, with a considerable excess of rain; but, from early in August to about the middle of September, there was a period of 6 weeks of warm and genial weather, from which time, till the end of September, it was again very cold, wet, and stormy. August was not only warm, but there was very little rain, whilst in September there was, towards the end of the month, a great excess of rain. The degree of humidity of the air was high in April and June, rather high in July, rather low in May, very low in August, and low in September.

The autumn of 1870 was thus changeable as to temperature, upon the whole cold, wet during the first half of September, and also of October, but afterwards comparatively dry and favourable for field work. The greater part of the winter was extremely severe, with a good deal of snow, and very cold winds; the remainder was mild and very wet, retarding field work and spring sowing; whilst winter corn was very backward, in many cases injured, pastures very bare, and vegetables very scarce. The hard winter had, however, killed many insects, and March was favourable for field work and sowing. With the exception of the latter half of April, the remainder of the spring was cold and backward. The rest of the active growing period was, excepting one or two intervals of short duration, cold, bleak, and very wet; hay was much damaged, corn crops were very backward, and in many cases much laid. In the greater part of England, however, August and the early part of September were warm and dry, much aiding the ripening and getting in of the crops; but the latter half of September was cold and wet.

With a very severe winter, a cold spring, more than the first half of the summer also cold, and a great excess of rain in June and July, the reports of the wheat crop of the country were, with few exceptions, unfavourable. The seed had mostly been got in well, but with a winter of intense frosts, and high east winds sweeping the snow which fell into the furrows, hollows, and hedges, much wheat was killed or injured. A good deal was ploughed up, some re-sown in the spring; the heavy soils suffered most, and the crops were much laid in July; but the ripening and harvest periods were more favourable. Still, the crop was estimated at much below the average in quantity, and considerably, though less, below the average in quality. Owing to the drought of the previous summer, and the frosts of the winter, the land was in a very healthy condition for spring-sowing; the weather was favourable in March, and spring crops were generally well got in. Barley was throughout the early portions of the season generally pronounced to promise well. Later, the heavier crops were a good deal laid; but at harvest the aggregate crop was concluded to be considerably over the average in quantity, and, for the most part, of fair, or even of good quality. Oats, on the other hand, were more generally less promising; injury from wire-worm was not unfrequent, and eventually the crop was estimated at under average.

In the experimental wheat-field the produce of both corn and straw was, by farmyard-manure, notably above the average of 28 years; but, without manure, and under nearly all conditions of artificial manuring, it was in a greater degree below the average, and proportionally more deficient in corn than in straw. The exception was the plot with mineral manure and nitrate of soda, which gave more than the average produce of straw, and proportionally less deficiency of corn, than the other artificial manures. The weight per bushel of corn was also considerably below the average in all cases excepting with farmyard manure and the mixture of mineral manure and nitrate of soda. The following results were obtained in the experimental barley field:—

TABLE XXI.—Quantity and Quality of Barley on Selected Plots. Twentieth Season, 1871.

Plots.	MANURES, PER ACRE.	PRODUCE PER ACRE, &c.					
		Dressed Corn.		Total Corn.	Straw and Chaff.	Total Produce (Corn and Straw).	Corn to 100 Straw.
		Quantity	Weight per Bush.				
		Bushels.	lbs.	lbs.	Cwts.	lbs.	
7	14 Tons Farmyard Manure	54¼	56·6	3243	37⅛	7401	78·0
1 O	Unmanured	16¾	55·0	973	11	2208	78·8
4 O	Mixed Mineral Manure ..	25	55·6	1438	14	3002	92·0
1 A	200 lbs. Ammonia-salts ..	36⅜	55·6	2129	23⅛	4712	82·5
4 A	Mixed Mineral Manure, and 200 lbs. Ammonia-salts ..	46½	56·5	2769	32½	6404	76·2
4 A A	Mixed Mineral Manure, and 275 lbs. Nitrate Soda (1)	46	56·3	2683	32⅝	6333	73·5
4 C	Mixed Mineral Manure, and 1000 lbs. (2) Rape-cake ..	47½	56·4	2809	32	6394	78·4

(1) 400 lbs. Ammonia-salts the first 6 years (1852–7), 200 lbs. the next 10 years (1858–67); 275 lbs. Nitrate Soda, 1868, and since.

(2) 2000 lbs. the first 6 years (1852–7).

The seed was sown on March 4; the more forward plots, which this season were only those manured with nitrate of soda and phosphates, and those with rape-cake, were cut on August 11 and 12, and carted on August 16; the remainder, indeed the majority, were cut on August 14 and 15, and carted on August 21. With nearly the whole of the active growing period cold and very wet, the crops of this, the twentieth season in succession of the growth of barley on the same land, were, under nearly all conditions of high manuring, more bulky than usual, but many of them were much laid. The excess of straw, compared with the average, was especially great with farmyard-manure. The proportion of corn to straw was in all cases below the average. But, with much improved weather at the ripening and harvest time, the actual quantity of corn per acre was, under most conditions of high manuring, and especially with farmyard manure, above the average; and the weight per bushel of dressed corn was, under all conditions without exception, above the average.

When speaking of the results obtained in the barley-field in the two years of summer drought, 1868 and 1870, particular attention was called to the fact that the plots manured with farmyard manure, or with nitrate of soda, withstood the drought much better than those manured with ammonia-salts. After the wet and cold spring and summer of 1871, the farmyard manure still gave very high total produce—indeed as high as in any year of the twenty excepting 1864; as heavy a weight of straw as in any year excepting 1864 and 1854; and as much corn as in any year excepting 1864 and 1863. But the nitrate-of-soda plots, though giving more corn, and considerably more straw, than in either of the years of drought, did not in this wet and cold season show the same superiority over the plots manured with ammonia-salts that they did in either 1868 or 1870. The nitrated plot—the results of which are quoted in the Tables (4 A A)—being one of the ripest in the field, suffered, it is true, considerably by the depredations of birds; but, independently of this, there is evidence enough that the nitrate did not show the same superiority over the ammonia-salts in the cold and wet as in the hot and dry season. Something may be due to the greater exhaustion of the nitrated plots in the preceding years of drought; but something is, doubtless, also due to more loss by drainage of the nitrogen of the spring-sown nitrate, than of that of the also spring-sown ammonia-salts, during the wet summer of 1871.

In connection with the fact, and the explanation, of the comparatively defective result with the nitrate in a wet summer when applied to barley, the very opposite result with wheat is of considerable interest. Thus, as already mentioned, there was, in the experimental wheat-field, much less deficiency of corn, and even an excess of straw, by the nitrate, as compared with the ammonia-salts. The explanation of the difference of effect with the two crops would seem to be, that whilst for the wheat the nitrate was not sown until the spring, the ammonia-salts had been sown in the previous autumn, and were subject to a considerable loss by drainage during several extremely wet periods of the winter, when there was no growth, and before the nitrate was sown. It will be remembered that a similar result was obtained with wheat after the wet winter of 1868-9; and also in other years, as referred to in the foot-note at p. 62.

Finally, it will be observed that the results obtained in the experimental fields are in the main in accord with the reports of the crops of the country at large, in showing a considerably deficient wheat-crop, and a barley-crop above the average both in quantity and quality, though the twentieth in succession on the same land.

Comparison of the Produce of Barley in the least, and in the most, productive Seasons of the Twenty.

The foregoing records of the characters of the seasons, and of the produce of barley in each individual year of the twenty, with the comments made upon them, very forcibly illustrate the diversity between one season and another, and how very varied is the final result, dependent on the mutual adaptations of heat,

TABLE XXII.—Quantity and Quality of Barley on Selected Plots, in the least, and in the most, productive Season of the twenty.

Plots.	MANURES, PER ACRE.	Least Productive Season, **1856.**	Most Productive Season, **1854.**	Difference over (or under –) **1856.**
	Weight per Bushel of Dressed Corn.			
		lbs.	lbs.	lbs.
7	14 Tons Farmyard Manure	47·1	53·9	6·8
1 O	Unmanured	49·1	53·6	4·5
4 O	Mixed Mineral Manure	47·0	54·0	7·0
1 A	200 lbs. Ammonia-salts	48·5	53·6	5·1
4 A	Mixed Min. Man., and 200 lbs. Ammonia-salts	46·4	54·3	7·9
4 A A	Mixed Min. Man., and 400 lbs. Ammonia-salts	45·4	52·1	6·7
4 C	Mixed Min. Man., and 2000 lbs. Rape-cake ..	46·3	52·8	6·5
	Total Corn per Acre, reckoned at 52 lbs. per Bushel.			
		Bushels.	Bushels.	Bushels.
7	14 Tons Farmyard Manure	31⅞	60⅛	28¼
1 O	Unmanured	15⅝	37¾	22⅛
4 O	Mixed Mineral Manure	19⅝	45⅝	26
1 A	200 lbs. Ammonia-salts	27½	53⅛	25⅝
4 A	Mixed Min. Man., and 200 lbs. Ammonia-salts	30¾	66	35¼
4 A A	Mixed Min. Man., and 400 lbs. Ammonia-salts	36¼	68	31¾
4 C	Mixed Min. Man., and 2000 lbs. Rape-cake ..	35⅜	65⅝	30¼
	Straw (and Chaff), per Acre.			
		Cwts.	Cwts.	Cwts.
7	14 Tons Farmyard Manure	19¾	37¼	17½
1 O	Unmanured	8¾	21¾	13
4 O	Mixed Mineral Manure	9⅜	23⅛	13¾
1 A	200 lbs. Ammonia-salts	17⅛	30¼	13⅛
4 A	Mixed Min. Man., and 200 lbs. Ammonia-salts	21¼	40½	19¼
4 A A	Mixed Min. Man., and 400 lbs. Ammonia-salts	33	49	16
4 C	Mixed Min. Man., and 2000 lbs. Rape-cake ..	30½	42⅛	11⅝
	Total Produce (Corn and Straw), per Acre.			
		lbs.	lbs.	lbs.
7	14 Tons Farmyard Manure	3866	7298	3432
1 O	Unmanured	1797	4405	2608
4 O	Mixed Mineral Manure	2075	4969	2894
1 A	200 lbs. Ammonia-salts	3347	6155	2808
4 A	Mixed Min. Man., and 200 lbs. Ammonia-salts	3981	7958	3977
4 A A	Mixed Min. Man., and 400 lbs. Ammonia-salts	5582	9026	3444
4 C	Mixed Min. Man., and 2000 lbs. Rape-cake ..	5257	8125	2868
	Corn to 100 Straw.			
7	14 Tons Farmyard Manure	74·9	75·0	0·1
1 O	Unmanured	82·4	80·4	–2·0
4 O	Mixed Mineral Manure	96·3	91·5	–4·8
1 A	200 lbs. Ammonia-salts	74·8	81·5	6·7
4 A	Mixed Min. Man., and 200 lbs. Ammonia-salts	67·1	75·7	8·6
4 A A	Mixed Min. Man., and 400 lbs. Ammonia-salts	51·0	64·5	13·5
4 C	Mixed Min. Man., and 2000 lbs. Rape-cake ..	53·9	72·4	18·5

moisture, and stage of growth of the crops. In no two years has one and the same manure yielded precisely the same result both as to the quantity and the quality of its produce. Nor have the seasons which have been more or less favourable than the average for one description of manure, been equally favourable or unfavourable for other descriptions.

Referring to the previous discussion, and to the materials brought together in the Appendix-Tables (pp. 179—201), for any more detailed consideration of the subject, it must suffice here, by way of illustration and summary, to call special attention to the produce yielded by the same description and quantity of manure in the least, and in the most, productive season of the twenty.

Table XXII. (see opposite page) shows, side by side, the quantity and quality of the produce obtained in 1854, which was upon the whole the most, and in 1856, which was upon the whole the least, productive of the twenty seasons; also the difference between the two. For the purposes of this illustration, the same selection of plots has been made as in the foregoing consideration of the produce of each individual season. It is true that one or other of the descriptions of manure specified may have given more corn, or a higher weight per bushel, or more straw, in some other season than it did in 1854, or a worse result, on some point or other, than in 1856. But, looking chiefly to the results obtained under the best conditions of manuring, and the general characters of the produce, there can be no doubt that the seasons selected do, upon the whole, represent, respectively, the least, and the most, productive of the series.

In the first place, the weight per bushel of dressed corn was from 4½ lbs. to nearly 8 lbs. less in the bad than in the good year, or from about 8½ to nearly 15 per cent. less in the one case than in the other. Under almost every condition of manuring, 1856 was the worst season, so far as this point is concerned; but several other seasons gave higher weight per bushel than 1854.

It is obvious that, with a difference of from 8½ to 15 per cent. in the weight of the bushel, a comparison of the actual number of bushels of dressed corn in the two seasons would much underrate the difference in the amount of produce, greatly to the disadvantage of the most productive one. Accordingly, the quantity of *total corn*, per acre, has, in each case, been calculated into bushels of the assumed uniform weight of 52 lbs. per bushel; and the results of this calculation are given in the second division of the Table.

There was, *without manure*, in the bad season about 15½, in the good season 37¾ bushels of corn, or a difference of rather more than 22 bushels between the two; and also a difference in the quantity of straw amounting to 13 cwts. per acre.

With *farmyard manure*, the unfavourable season of 1856 gave scarcely 32 bushels, whilst 1854 gave rather over 60 bushels, or a difference of 28¼ bushels of corn; and there was also a difference of 17½ cwts. of straw.

Lastly, the three most productive artificial manures gave, respectively, in 1856, 30¾, 36¼, and 35⅜ bushels of corn, and in 1854, 66, 68, and 65⅝ bushels, or a difference in favour of the good year of 35¼, 31¾, and 30¼ bushels of corn, besides 19¼, 16, and 11⅝ cwts. of straw.

Thus, with one and the same expenditure for manure, there was a difference in the quantity of produce obtained in the two seasons of from 30 to 35 bushels of corn, and in one case of nearly a ton of straw, or not much less than would represent the average barley-crop of many localities.

It is worthy of remark that, whilst the season of 1856 was far worse than that of 1853 as regards both the quantity and the quality of the barley-crop, 1853 was, for the experimental wheat (which that year could not be sown until the spring), in every particular worse than 1856. Again, whilst 1854 was a decidedly more productive barley-year than 1863, yielding under almost every condition of manuring not only more corn, but considerably more straw—in other words, a greater quantity of total produce, indicating greater luxuriance—1863 was, on the other hand, a considerably more productive wheat-year than 1854, and especially so in corn. Both years were, however, remarkable for very large produce of both corn and straw, of both wheat and barley.

The years next in order of productiveness, so far as the barley crop is concerned, were 1857 and 1864, which were very good wheat years also. But neither 1863, nor either of the two years last mentioned, yielded anything like the same amount of total crop, corn and straw together, as 1854. The years next in order to 1856 in point of badness of barley-crop were 1859, 1860, 1868, and 1870; the deficiency in the two last-mentioned years being due to summer heat and drought, but in the other two seasons to very opposite conditions.

The question arises—to what characters of season are the extreme differences of produce which have been traced to be attributed? Referring to the details already given respecting each individual season, so far as the other years above enumerated are concerned, it must suffice here to recall attention to the distinctive characters of the season of 1856 yielding the worst, and of 1854 yielding the best, barley-crop of the twenty years.

The very unusually productive season of 1854 had been preceded by a very severe winter; March and April were upon the whole warmer than usual, but May, June, July, and August were pretty uniformly below the average temperature; whilst in March, April, June, and July there was a very considerable deficiency of rain, though more than the average number of rainy days. In May, however, there was about double the usual amount of rain, and an unusually large number of rainy days. In August, again, there was a full amount of rain, which, however, fell for the most part in heavy showers, and the month was upon the whole favourable for ripening and harvest.

Thus, the season of 1854 was characterised by prevailing low rather than high temperatures, an abundance of rain at the period of early active growth (doubtless favouring root development), and again before harvest, but otherwise by dryness as well as coolness. It would seem, therefore, that the large produce was due to a sufficiency of moisture within the soil when most wanted, with, at other times, comparatively dry and temperate atmospheric conditions, resulting in a continuity of unchecked growth, rather than in very active luxuriance at intervals.

Compared, or rather contrasted, with the above climatic conditions, those of the extremely unfavourable season of 1856 were as follows:—

There had been some severe weather in the early part of the winter, but the later and greater part was upon the whole mild. March, April, and especially May, were colder than the average, whilst June, July, and August, though showing average day-temperatures fully as high as usual, were very changeable, and in June and July the nights were cold. In each of the months of January, February, March, April, May, June, and July, there was considerably more rain than in the corresponding months of 1854—in all nearly 6 inches more; whilst, in April there was an excess over the average, in May more than double the average, and in August again an excess.

The season of 1856 was, therefore, characterised by a great excess of rain during the early periods of growth; considerably more than in 1854, and there was, besides, considerably more than in that year, both before and after that period. There were also, almost throughout, great fluctuations, and high ranges, of temperature. In other words, the season was very wet, with marked alternations of heat and cold, whilst it was, for the period of the year, the coldest during the time of the greatest excess of rain. Finally, there were heavy rains, with considerable fluctuations of temperature, about the ripening and harvest period. The very bad result in this season would seem to be due, therefore, to an excess of rain, with, at the same time, great alternations of temperature, during the most active periods of growth, entirely preventing continuity of progress; whilst the unhealthy plant thus produced was subjected to unfavourable maturing conditions.

The above description of the climatic conditions of the two seasons, as collated from meteorological records, will probably strike the reader as not showing so great a contrast as would be expected between the season of the greatest, and that of the least, productiveness of the twenty. Certainly 1854 was not marked by individual periods of more than ordinarily active luxuriance; the circumstances were rather those of steady and unbroken accumulation, followed by favourable maturing conditions. The extremely productive season of 1863 showed in this respect similar characteristics. It should be remembered, indeed, that both wheat and barley will flourish under very temperate conditions. Again, the record of the climatic circumstances under which the extremely bad crop of 1856 was produced, shows some points in respect to which, considered by themselves, it might be judged to have been more favourable for luxuriance than 1854. It is only when the fluctuations of temperature, the continuity of the wetness, and the adaptations of heat and moisture to stage of growth, are borne in mind, that the result becomes intelligible.

These two instances, so strikingly contrasted in their results, forcibly illustrate the necessity, not only of very careful and detailed study of the meteorological registry, but also of due consideration of its indications in their bearings upon the coincident stage and tendency of growth of the plant, if we would attain any really clear conception of the connection between the ever fluctuating characters of season, and the equally fluctuating characters of growth and produce.

Comparison of the average Annual Produce of Barley over the first 10, *the second* 10, *and the total period of* 20 *years.*

There is still another point in connection with the influence of season upon the crop, which should be considered before treating more exclusively of the effects of the different manures. Thus, before attempting to compare the effects of different manures, used year after year on the same plot, it is obviously necessary to form a judgment whether the earlier or the later seasons of the series were, in themselves, the most favourable, so as to distinguish as far as possible between the results due, on the one hand to more or less favourable seasons, and on the other to the direct action of the manures, in maintaining a suitable balance of the required constituents in the soil, or in inducing exhaustion, or accumulation, as the case may be.

TABLE XXIII.—Average Annual quantity and quality of Barley, on Selected Plots, over the first 10 years, the second 10 years, and the Total Period of 20 years.

Plots.	MANURES, PER ACRE.	AVERAGE ANNUAL PRODUCE, &c.			Second 10 Years over (or under −) First 10.
		First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period 20 Years, 1852–'71.	
	Weight per Bushel of Dressed Corn.				
		lbs.	lbs.	lbs.	Per Cent.
7	14 Tons Farmyard Manure	52·6	56·0	54·3	6·5
1 O	Unmanured	51·6	53·1	52·3	2·9
4 O	Mixed Mineral Manure	52·3	54·6	53·4	4·4
1 A	200 lbs. Ammonia-salts	51·2	53·0	52·1	3·5
4 A	200 lbs. Amm.-salts, Mixed Min. Man.	52·2	55·7	54·0	6·7
	Total Corn per Acre, reckoned at 52 lbs. per Bushel.				
		Bushels.	Bushels.	Bushels.	Per Cent.
7	14 Tons Farmyard Manure	$48\frac{7}{8}$	$57\frac{1}{2}$	$53\frac{1}{4}$	17·6
1 O	Unmanured	$24\frac{5}{8}$	$18\frac{7}{8}$	$21\frac{3}{4}$	−23·4
4 O	Mixed Mineral Manure	$32\frac{7}{8}$	$26\frac{5}{8}$	$29\frac{3}{4}$	−16·0
1 A	200 lbs. Ammonia-salts	$36\frac{3}{4}$	34	$35\frac{3}{8}$	− 7·5
4 A	200 lbs. Amm.-salts, Mixed Min. Man.	$49\frac{3}{4}$	$51\frac{1}{4}$	$50\frac{1}{2}$	3·0
	Straw (and Chaff), per Acre.				
		Cwts.	Cwts.	Cwts.	Per Cent.
7	14 Tons Farmyard Manure	$26\frac{5}{8}$	$29\frac{7}{8}$	$28\frac{1}{4}$	12·2
1 O	Unmanured	$13\frac{3}{8}$	$10\frac{1}{4}$	$11\frac{3}{4}$	−23·4
4 O	Mixed Mineral Manure	$16\frac{1}{8}$	$12\frac{5}{8}$	$14\frac{3}{8}$	−21·7
1 A	200 lbs. Ammonia-salts	$19\frac{3}{4}$	$17\frac{3}{8}$	$18\frac{1}{2}$	−12·0
4 A	200 lbs. Amm.-salts, Mixed Min. Man.	$28\frac{7}{8}$	28	$28\frac{1}{2}$	− 3·0
	Total Produce (Corn and Straw), per Acre.				
		lbs.	lbs.	lbs.	Per Cent.
7	14 Tons Farmyard Manure	5525	6342	5933	14·8
1 O	Unmanured	2782	2126	2454	−23·6
4 O	Mixed Mineral Manure	3517	2807	3162	−20·2
1 A	200 lbs. Ammonia-salts	4119	3719	3919	− 9·7
4 A	200 lbs. Amm.-salts, Mixed Min. Man.	5827	5808	5817	− 0·3
	Corn to 100 Straw.				
7	14 Tons Farmyard Manure	85·6	91·3	88·5	6·7
1 O	Unmanured	85·9	87·3	86·6	1·6
4 O	Mixed Mineral Manure	95·1	97·7	96·4	2·7
1 A	200 lbs. Ammonia-salts	86·4	91·9	89·2	6·4
4 A	200 lbs. Amm.-salts, Mixed Min. Man.	79·9	86·4	83·2	8·1

In Table XXIII. (p. 77) there is given the average produce over the first ten, the second ten, and the total period of twenty years, by very different descriptions of manure, and a comparison of the results will illustrate the point in question. The plots selected are 5 out of the 7 quoted in the preceding Tables, namely—that manured with farmyard manure every year; the continuously unmanured plot; the one with mixed mineral manure alone every year; that with 200 lbs. ammonia-salts alone every year; and that with both mixed mineral manure and 200 lbs. ammonia-salts every year. It is obvious that these five plots supply very various, and very opposite soil-conditions, so that the comparative effects of the seasons on each must have considerable significance.

In the first place, there is, with each of the five very opposite conditions of manuring, a considerably higher average weight per bushel of dressed corn over the second, than over the first ten years of the twenty; and the superiority is the greatest with the highest manuring and the heaviest crops—namely, with farmyard manure, and with ammonia-salts and mixed mineral manure together. The proportion of corn to straw is also the higher over the last ten years, and the higher with the heavier crops. Further evidence that the later years were in the main more favourable than the earlier, at least for the production and maturation of grain, is to be found in the fact that there was also a less proportion of offal corn during the second half of the total period.

With a considerable difference in the weight per bushel of the dressed corn, it is obvious that the comparative productiveness of the two periods will not be accurately represented by the actual number of bushels of dressed corn in each case. Accordingly, as before, the quantity of *total corn* has been calculated into assumed bushels of the uniform weight of 52 lbs. These results show, without manure, with mineral manure alone, and with ammonia-salts alone—that is, with defective soil-conditions, a considerable deficiency of corn over the second half of the period; the greater the more defective the manuring, and the greater the relative deficiency of nitrogen in the soil; for the falling off is considerably more marked with mineral manure alone, than with ammonia-salts alone. Under the same three soil-conditions there is as great, or even a greater deficiency of straw, and consequently of total produce also, during the later years.

With farmyard manure, on the other hand, the annual use of which has resulted in a very great accumulation within the soil, not only of nitrogen, but probably of every mineral constituent also, there has been a considerable excess of produce of both corn and straw, but especially of corn, over the second as compared with the first ten years.

With the ammonia-salts and mixed mineral manure together, by which also the soil has become much richer in most mineral constituents, and at any rate less exhausted if not richer in nitrogen than without manure or with mineral manure alone, there is again a slight increase of corn, but a slight deficiency of straw, over the later years.

The general conclusion from the above results, as well as from others, not here specially referred to, is, that the earlier years of the twenty were, on the average, as favourable, if not more favourable, for quantity of total produce—that is for luxuriance—than the later; but that the later seasons were much more favourable for tendency to seed-forming, and also for the maturation of the grain.

Bearing in mind this conclusion as to the progressive or retrogressive characters of the seasons themselves, we shall be in a position the better to judge of the effects of the different manures when used year after year, for twenty years in succession, on the same land.

Section II.—Average Annual Produce by each Description of Manure employed.

In this section the object will be to consider more exclusively than hitherto the effects of different manures on the barley-crop; to ascertain what conditions of manuring are the best adapted for the crop in the soil in question; to determine in what constituent, or class of constituents, the soil soonest shows signs of exhaustion by its growth; and to compare the characters of barley with those of wheat in these respects. To this end attention will chiefly be confined to the average results obtained by each manure over a series of years, so as to exclude, as far as possible, the influence of variations of season, the full consideration of which already has so clearly indicated, and so greatly limited, the necessary reference to it here.

With regard to the soil, as already stated, the experimental barley-field immediately adjoins the experimental wheat-field. The soil of both may be described as—"a somewhat heavy loam, with a subsoil of raw yellowish red clay, but resting in its turn upon chalk, which provides good natural drainage." Lastly, the wheat-field is artificially pipe-drained, but the barley-field is not.

The particulars of the manuring, and of the average annual produce, and increase, by manure, on each plot, over the twenty years, are given at one view in the folding Table (XXIV.) facing the next page. The full details will be found in the Appendix Tables (pp. 179-201); and such abstracts as may be needed for the illustration of individual points will be given as we proceed.

Average Annual Produce without Manure.

From the commencement, two plots, at some distance from one another, have been left unmanured; and a third has received, every year, a dressing of ashes (burnt soil and turf), at the rate of 20 bushels per acre per annum. This is much more than the quantity of the same description of ashes mixed with the various artificial manures to aid their even distribution over the land. The experiment was arranged to meet the cavil of Baron Liebig, that inasmuch as we had mixed "ashes" with our manures, we could not form any judgment as to the effects of the latter; and that doubtless part of the effect we attributed to them was due to the "ashes" also employed.

Table XXV. (see page 81) gives the average annual produce on these three practically unmanured plots, over the first ten, the second ten, and the total period of twenty years.

Looking first to the quality of the produce, the average weight per bushel of dressed corn is, on all three plots, considerably higher, and the proportion of corn to straw is either higher, or but little lower, over the last than over the first 10 years.

This result is doubtless due, in great measure, to the character of the seasons; but the fact may be taken as at any rate sufficient evidence that there was no deterioration in the character or health of the plant, from growing the same crop year after year on the same land.

The two unmanured plots, at opposite sides of the field, show an average annual difference, over 20 years, of 2 bushels of corn and $\frac{5}{8}$ cwt. of straw, but considerably less over the last 10, than over the first 10 years. This indicates probably, that the result is, in part, at any rate, due to a difference of condition from previous manuring and cropping, which is becoming gradually reduced, and so the plots the more equalised. It is a question, however, whether the staple may not be rather better on Plot 6–1 than on Plot 1–O.

On the other hand, the average produce on Plot 6–2, receiving annually 20 bushels of soil and turf, ashes per acre, is only precisely the same in corn, and even rather less in straw, than on the immediately adjoining plot (6–1), which is entirely unmanured. Over the first 10 years, indeed, the ashed plot gave rather less, both corn and straw, than the entirely unmanured one, though rather more of both over the second 10 years. Possibly, therefore, under the exhausting process of growing the crop year after year on the same land, the small amount of manurial matters supplied in the ashes may eventually—that is after, so to speak, all the previously acquired *condition* is worked out of the soil

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s othe	CORN.	AL PRODUCE.		PLOTS.
	Over corresponding Mineral Manures.	Ove Unmanred.	Over corresponding Mineral Manures.	
	Bushels.	lbs	lbs.	
(	..	..	..	1 O.
cas . .	..	25	..	2 O.
aci . .	..	8	..	3 O.
. .	..	36	..	4 O.
cwt				
fir				
(. .	..	65	..	1 A.
6 y . .	21½	147	2829	2 A.
ps. St	12⅝	80	1676	3 A.
ps. St	18¾	144	2655	4 A.
Su				
(. .	..	90	..	1 AA. } (5)
ins . .	23¾	160	3286	2 AA.
an Sulp	15	94	2167	3 AA.
sal Sulp	22¼	162	3281	4 AA.
So				
to				
" A . .	..	11(	..	1 AAS. } (5)
. .	22¾	178	3138	2 AAS.
(3) S	20¼	14	2630	3 AAS.
no (3) S	22½	18	3249	4 AAS.
Sil				
app				
Sil . .	..	13	..	1 C. } (7)
cor . .	21¼	147	2913	2 C.
plo Sulph	21¼	13(	2886	3 C.
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ph men	..	1	..	M.
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and				
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. .	..		..	2 }
. .	20¾	15	2771	7

—maintain the yield at a slightly higher point than it will reach on the absolutely unmanured land.

TABLE XXV.—Average Annual Produce of Barley without Manure, and with Ashes (burnt soil and turf.)

Plots.		AVERAGE ANNUAL PRODUCE. First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	Second 10 Years over (or under—) First 10.
	Dressed Corn, per Acre—Bushels.				
					Per Cent.
1 O	Unmanured continuously	22⅜	17½	20	−21·8
6 1	Unmanured continuously (duplicate)	25	18⅞	22	−24·5
6 2	20 Bushels ashes	23⅞	20	21⅞	−16·2
	Total Corn, per Acre—lbs.				
1 O	Unmanured continuously	1281	985	1133	−23·1
6 1	Unmanured continuously (duplicate)	1414	1070	1242	−24·3
6 2	20 Bushels ashes	1352	1138	1245	−15·8
	Straw (and Chaff), per Acre—Cwts.				
1 O	Unmanured continuously	13⅜	10¼	11¾	−23·4
6 1	Unmanured continuously (duplicate)	14	10¾	12⅜	−23·2
6 2	20 Bushels ashes	13	11¼	12⅛	−13·5
	Total Produce (Corn, Straw, and Chaff), per Acre—lbs.				
1 O	Unmanured continuously	2782	2126	2454	−23·6
6 1	Unmanured continuously (duplicate)	2987	2273	2630	−23·9
6 2	20 Bushels ashes	2814	2391	2603	−15·0
	Weight per Bushel of Dressed Corn—lbs.				
1 O	Unmanured continuously	51·6	53·1	52·3	2·9
6 1	Unmanured continuously (duplicate)	51·5	53·5	52·5	3·9
6 2	20 Bushels ashes	51·6	53·6	52·6	3·9
	Corn to 100 Straw.				
1 O	Unmanured continuously	85·9	87·3	86·6	1·6
6 1	Unmanured continuously (duplicate)	89·8	89·4	89·6	− 0·4
6 2	20 Bushels ashes	92·0	90·9	91·4	− 1·2

At any rate, the fact that the plot manured with ashes has,

over 20 years, not given any more produce than the immediately adjoining unmanured plot, is a sufficient answer to the objection that the admixture of a much smaller quantity of the same description of ashes with the artificial manures used on the other plots, in any way vitiates the results, or obscures the proper interpretation of them.

The average annual produce of barley on the land in question, without manure, may be taken at about 21 bushels of grain, and 12 cwts. of straw.

It will be of interest to compare the produce of barley without manure with that of wheat in the immediately adjoining field. Table XXVI. (see next page) illustrates the point; and for the sake of easier comparison, the produce of both crops is given in pounds. For wheat the average annual produce is given—for the whole 28 years of the experiments; for the first 20 years, which will, perhaps, best compare with the barley, so far as condition of land at the commencement of the series is concerned; and for the last 20 years, which comprise the same period as that of the barley results, and will, hence, compare best so far as any influence of season is concerned, but which succeeds 8 years of the growth of the crop without manure. For the barley, the mean produce of the two unmanured plots (1–O and 6–1) is given.

It is seen that, over a period of 20 years without manure, the barley has yielded a greater weight of corn, but less of straw, per acre, per annum, than the wheat. This is the case, whether the produce of wheat be averaged over the whole 28, the first 20, or the last 20 years. The average weight of total produce (corn and straw together) is, however, much more nearly the same for both crops. It is almost identical when the comparison is made with the wheat averaged over the whole 28 years; it is in favour of the wheat when the first 20 years of each crop is taken, and in an almost exactly equal degree in favour of the barley when both crops are taken over the same period, namely, the 20 years—1852–'71, which, in the case of the wheat, succeeded the removal of eight previous unmanured crops, but in that of the barley were the first 20 years of its continuous growth.

Prior to the commencement of the experiments the previous cropping had been as under:—

Wheat-Field.	*Barley-Field.*
Turnips (dunged).	Turnips (dung and superphosphate) carted off.
Barley.	Barley.
Peas.	Clover.
Wheat.	Wheat.
Oats	Barley (sulphate ammonia).

TABLE XXVI.—Average Annual Produce of Wheat, and of Barley, without Manure.

	Average Annual Produce, &c.				Barley more (or less—) than Wheat.		
	First Half of Period.	Second Half of Period.	Total Period.	Second Period over (or under—) First Period.	First Half of Period.	Second Half of Period.	Total Period.
Total Corn, per Acre.							
Wheat:—	lbs.	lbs.	lbs.	Per Cent.	lbs.	lbs.	lbs.
28 years, 1844–1871	1053	891	972	−15·4	295	137	216
20 years, 1844–1863	1018	1035	1026	1·7	330	− 7	162
20 years, 1852–1871	944	881	913	− 6·7	404	147	275
Barley:—							
20 years, 1852–1871	1348	1028	1188	−23·7			
Straw (and Chaff), per Acre.							
Wheat:—							
28 years, 1844–1871	1713	1355	1534	−20·9	−176	−183	−180
20 years, 1844–1863	1693	1693	1693	..	−156	−521	−339
20 years, 1852–1871	1663	1241	1451	−25·4	−126	− 69	− 97
Barley:—							
20 years, 1852–1871	1537	1172	1354	−23·7			
Total Produce (Corn, Straw, and Chaff), per Acre.							
Wheat:—							
28 years, 1844–1871	2766	2246	2506	−18·8	119	− 46	36
20 years, 1844–1863	2711	2728	2719	0·6	174	−528	−177
20 years, 1852–1871	2607	2122	2364	−18·6	278	78	178
Barley:—							
20 years, 1852–1871	2885	2200	2542	−23·7			

It is possible, therefore, that there would be rather more *nitrogenous condition* to work out of the barley than out of the wheat land. Consistently with this, the barley gives much more excess of corn, and much less deficiency of straw, compared with the wheat in the earlier years. It also shows much more rapid decline in total produce than the wheat. The evidence leads to the conclusion, therefore, that the wheat will eventually maintain a somewhat higher total produce than the barley. This is what would be expected with the autumn-sown crop, with its longer period for root-development, and consequent possession of a greater range of soil for the collection of food.

It has already been shown that what may be termed, in an agricultural sense, corresponding crops of wheat and barley, require very nearly identical amounts of the different constituents to be available within the soil. These results show, experimentally, how nearly equal are the amounts of *gross produce* of the two crops, which a soil in a given condition will yield; and it seems probable that the only difference will be that which is due to varying adaptation of season, and to the greater or less root-range of the one crop or the other.

Average Annual Produce by Farmyard Manure.

Table XXVII. shows the average annual produce of barley, and the increase over the mean produce without manure, by an annual dressing of 14 tons of farmyard manure per acre.

TABLE XXVII.—Average Annual Produce, and Increase of Barley by Farmyard Manure (Plot 7.)

	AVERAGE ANNUAL PRODUCE, &c.				INCREASE OVER (or under		
					UNMANURED (Plots 1 O and		
	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	Second 10 Years over (or under –) First 10 Years.	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	To Peri 20 Y 1852-
				Per Cent.			
Dressed Corn per acre .. .. .. bushels	45	51½	48¼	14·4	21⅜	33⅜	2
Total Corn per acre .. .. lbs.	2541	2995	2768	17·9	1193	1967	158
Straw (and Chaff) per acre .. .. cwts.	26⅝	29⅞	28¼	12·2	12⅞	19⅜	1
Total Produce (Corn, Straw, &c.) per acre lbs.	5525	6342	5933	14·8	2640	4141	339
Weight per Bushel of Dressed Corn lbs.	52·6	56·0	54·3	6·5	1·0	2·7	1·
Corn to 100 Straw	85·6	91·3	88·5	6·7	–2·3	3·0	0·

Unlike the produce without manure, that by farmyard manure was, in every particular of quantity, as well as quality, considerably higher over the second than over the first 10 years. Taking the average of the first 10 years, the produce of corn was exceeded by several, and that of straw by more, of the artificial manures; but, over the second 10 years, it was in no case exceeded in average amount of corn, and in only one case in amount of straw. Averaged over the whole period of 20 years, however, several of the mixtures of mineral and nitrogenous manure approached, and some even surpassed, it in produce of corn, more did so in straw, and several in total produce (corn and straw together).

The individual years in which the dunged plot, more or less, exceeded all others, were—in produce of corn, 1859, 1862, 1864, 1865, 1866, 1867, and 1871; in produce of straw, 1862 and

1866; and in total produce, 1859, 1862, 1865, 1866, and 1871. For information as to the characters of season, under the influence of which these results were obtained, we must refer to the description of the respective seasons in Section 1.

Whilst the unmanured land gave an average annual produce of only 21 bushels of dressed corn, and about 12 cwts. of straw, the farmyard manure gave $48\frac{1}{4}$ bushels of dressed corn, and $28\frac{1}{4}$ cwts. of straw; or an average increase over the mean unmanured of $27\frac{1}{4}$ bushels of corn, and $16\frac{1}{8}$ cwts. of straw.

During the 20 years, 280 tons of dung, containing from 80 to 90 tons of dry solid matter, have been applied per acre. But the produce has only amounted to about $24\frac{3}{4}$ tons of corn, and $28\frac{1}{4}$ tons of straw, or in all to only 53 tons; and the increase, over the produce without manure, has only been about $14\frac{1}{8}$ tons of corn, and $16\frac{1}{8}$ tons of straw—in all $30\frac{1}{4}$ tons of total increase; which certainly would contain less than one-third as much dry solid matter as was supplied in the dung. The manure would, in fact, supply to the soil very much more of carbon, of nitrogen, of phosphoric acid, of potass, of lime, of magnesia—indeed, probably of every constituent, than the total produce contained; and, of course, a still greater excess over the amounts taken off in the *increase* of produce.

It is evident that there must be a very great accumulation of constituents in the soil of the dunged plot. Of nitrogen, for example, from 3 to 4 times as much has been applied as to any of the artificially manured plots; and, judging from the determinations of nitrogen in the soil of the dunged plot in the wheat-field, it is probable that the percentage of that substance in the surface-soil of the dunged barley plot has, during the 20 years, been nearly doubled. Yet, mixtures of mineral manure and ammonia-salts, or nitrate of soda, supplying nitrogen in so much less quantity, but in a more readily available condition, frequently gave about the same, and sometimes more, produce than the dung. It is obvious, too, that the large amount of nitrogen accumulated in the soil of the dunged plot is in a far less available or effective condition than the much smaller quantities annually supplied as ammonia-salts or nitrate of soda.

In order to ascertain in what degree the accumulated nitrogen and other constituents will be annually available, and for what length of time any residue will remain effective, the dunged plot has, since the removal of the twentieth crop, been divided into two portions—one to receive dung annually, as before, and the other to be left unmanured, probably until the produce on it approximates to that of the continuously unmanured plot.

The following Table shows the results obtained by the annual application of 14 tons of dung per acre, for barley, and for wheat, respectively. As before, the produce is, for easy comparison, given in pounds, and that of the wheat is averaged over the whole 28, the first 20, and last 20 years.

TABLE XXVIII.—Average Annual Produce of Wheat, and of Barley, by 14 tons Farmyard Manure per Acre, per Annum.

	Average Annual Produce, &c.						
	First Half of Period.	Second Half of Period.	Total Period.	Second Period over (or under –) First Period.	Barley over (or under –) Wheat. First Half of Period.	Barley over (or under –) Wheat. Second Half of Period.	Barley over (or under –) Wheat. Total Period.
Total Corn, per Acre.							
Wheat:—	lbs.	lbs.	lbs.	Per Cent.	lbs.	lbs.	lbs.
28 years, 1844–1871	1953	2335	2144	19·6	588	660	624
20 years, 1844–1863	1757	2395	2076	36·3	784	600	692
20 years, 1852–1871	2145	2385	2265	11·2	396	610	503
Barley:—							
20 years, 1852–1871	2541	2995	2768	17·9			
Straw (and Chaff), per Acre.							
Wheat:—							
28 years, 1844–1871	3332	3801	3567	14·1	–348	–454	–402
20 years, 1844–1863	3071	3960	3515	28·9	– 87	–613	–350
20 years, 1852–1871	3795	3803	3799	0·2	–811	–456	–634
Barley:—							
20 years, 1852–1871	2984	3347	3165	12·2			
Total Produce (Corn, Straw, and Chaff), per Acre.							
Wheat:—							
28 years, 1844–1871	5285	6136	5711	16·1	240	206	222
20 years, 1844–1863	4828	6355	5591	31·6	697	– 13	342
20 years, 1852–1871	5940	6188	6064	4·2	–415	154	–131
Barley:—							
20 years, 1852–1871	5525	6342	5933	14·8			

The produce of wheat as well as of barley was considerably higher over the later than over the earlier years; but the rate of increase was very much less over the last 20 than over the first 20 of the total 28 years. It may be mentioned here, in passing, that in only 4 of the 28 years has the produce of wheat-grain been higher on the dunged than on any of the artificially manured plots, namely, in 1855, 1859, 1866, and 1871; and in every year it has been surpassed in weight of straw, and of total produce (corn and straw together), on one or more of the artificially manured plots.

As without manure, so with farmyard manure, over whichever period the wheat is averaged, the barley gives a considerably greater quantity of corn, but considerably less straw, than the wheat. Of total produce, however, when the wheat is averaged over the whole 28 years, the barley gives (over 20 years) an average annual excess of 222 lbs. over the wheat; when the first 20 years of wheat is taken the excess of barley is 342 lbs. per acre per annum; but when both wheat and barley are taken over the same 20 years (in the case of the wheat after 8 preceding years of the same manuring and cropping), the barley gives a slight average annual deficiency of total produce, namely, 131 lbs.*

From these facts it may be concluded that, excepting differences due to season, or other incidental causes, a given amount of farmyard manure annually applied to a given soil will, when averaged over a sufficient period, yield identical amounts of total produce of the autumn-sown and autumn-manured wheat, and of the spring-sown and spring-manured barley.

The practice of applying 14 tons of farmyard manure per acre, per annum, is, it is true, as unusual as that of growing either wheat or barley so many years in succession on the same land. Nevertheless, the results of such an experiment are of much interest. They may be briefly summarised as follows:—With the great accumulation of constituents within the soil, the produce of both crops is higher in the later than in the earlier years; much more corn, but much less straw, was obtained with the spring-sown and spring-manured barley, than with the autumn-sown and autumn-manured wheat; but the two crops gave almost identical amounts of average annual total produce (corn and straw together). Notwithstanding that the dung supplied several times as much nitrogen, and more of all other constituents, its produce seldom exceeded that of some of the artificial mixtures of mineral manure and ammonia-salts, or nitrate of soda.

Lastly in regard to the effects of the farmyard manure, attention has been called (pp. 55–57 and 67) to the influence of the accumulated matter on the physical condition of the soil, increasing its porosity, enabling it to retain more moisture, and rendering the crop much less liable to injury from adverse climatic conditions, and especially from drought. Future experi-

* The general result is the same whether the acreage *produce* of the two crops be compared, as above, or only the *increase* of produce by manure; and as in adopting the increase as the basis of comparison, the diminution of produce without manure (which moreover was different for the two crops) would be a necessary element affecting the calculation, it is concluded that, for the purpose in view, the comparison of the *produce* of the two crops is less open to objection than that of the *increase*.

ment will show in what degree the accumulated residue from the previous manuring is effective for succeeding crops; and the effects of the different artificial manures now to be considered, will show to what constituents of the dung the increase of produce it has yielded has most probably been mainly due.

Average Annual Produce by purely Mineral Manure.

Under this head attention will chiefly be directed to the results obtained on the plots, and by the manures, as under:—

Plot 2 O—Superphosphate of Lime.

Plot 3 O—"Mixed Alkali-salts"—a mixture of sulphates of Potass, Soda, and Magnesia.

Plot 4 O—"Mixed Mineral Manure"—a mixture of the "Superphosphate of Lime," and the "mixed Alkali-salts."

Table XXIX. shows the average annual produce and increase by these manures. (See next page.)

The first point to remark is that, as without manure and with farmyard manure, so with these purely mineral manures, the weight per bushel of dressed corn is, in each case, considerably higher over the second than over the first 10 years. The proportion of corn to straw is also higher over the later years. This result is doubtless in great measure due to season. Still it is clear that in these points of *quality* there is no deterioration in the crop.

In point of *quantity*, however, the result is very different. There is, with each of the manures, a very considerable falling off in the average annual amount of corn, of straw, and of total produce, over the second as compared with the first 10 years; and rather more where the salts of potass, soda, and magnesia, are used, whether alone or in admixture with superphosphate, than where the superphosphate is used alone. Where the superphosphate and mixed alkali-salts are used together, the greater falling off in the later as compared with the earlier years would seem to be connected with a higher produce by that manure than by the superphosphate alone in the earlier years; whilst, in the later years, the produce by the two manures approximates more closely. Lastly on this point, the average annual increase over the unmanured produce is not, by either manure, widely different over the two periods; but where the superphosphate and the mixed alkali-salts are each used separately, the increase is rather greater, and where they are used together rather less, over the second 10 years—indicating a slightly less rate of decline than without manure with the two former, and a slightly greater decline with the more complete manure—accounted for by its proportionally greater increase over the earlier years.

TABLE XXIX.—Average Annual Produce, and Increase, by purely Mineral Manures.

Plots.	MANURES PER ANNUM.	AVERAGE ANNUAL PRODUCE, &c.				INCREASE OVER (or under −) UNMANURED (Plots 1 O and 6-1.)		
		First 10 Years, 1852-'61.	Second 10 Years, 1862-'71.	Total Period, 20 Years, 1852-'71.	Second 10 Years over (or under −) First 10.	First 10 Years, 1852-'61.	Second 10 Years, 1862-'71.	Total Period, 20 Years, 1852-'71.
	Dressed Corn, per Acre—Bushels.							
					Per Cent.			
2 O	Superphosphate ..	28	23¼	25⅝	−17·0	4¼	5	4⅝
3 O	Mixed Alkali-salts ..	24⅞	20⅛	22½	−19·1	1⅛	1⅞	1½
4 O	Superphosphate and Mixed Alkali-salts	30⅝	24½	27½	−20·0	6⅞	6¼	6½
	Total Corn, per Acre—lbs.							
2 O	Superphosphate ..	1562	1317	1439	−15·7	214	289	252
3 O	Mixed Alkali-salts ..	1396	1139	1268	−18·4	48	112	80
4 O	Superphosphate and Mixed Alkali-salts	1712	1387	1550	−19·0	365	360	363
	Straw (and Chaff), per Acre—Cwts.							
2 O	Superphosphate ..	14⅞	11⅞	13⅜	−20·2	1⅛	1⅜	1¼
3 O	Mixed Alkali-salts ..	13⅞	10¾	12¼	−22·5	⅛	¼	¼
4 O	Superphosphate and Mixed Alkali-salts	16⅛	12⅝	14⅜	−21·7	2⅜	2⅛	2¼
	Total Produce (Corn, Straw, and Chaff), per Acre—lbs.							
2 O	Superphosphate ..	3223	2639	2931	−18·1	338	439	389
3 O	Mixed Alkali-salts ..	2944	2338	2641	−20·6	59	138	99
4 O	Superphosphate and Mixed Alkali-salts	3517	2807	3162	−20·2	632	607	621
	Weight per Bushel of Dressed Corn—lbs.							
2 O	Superphosphate ..	52·1	54·4	53·2	4·4	0·6	1·1	0·8
3 O	Mixed Alkali-salts ..	51·8	54·3	53·0	4·8	0·3	1·0	0·6
4 O	Superphosphate and Mixed Alkali-salts	52·3	54·6	53·4	4·4	0·8	1·3	1·0
	Corn to 100 Straw.							
2 O	Superphosphate ..	93·8	100·4	97·1	7·0	5·9	12·0	9·0
3 O	Mixed Alkali-salts	90·0	94·7	92·4	5·2	2·1	6·3	4·3
4 O	Superphosphate and Mixed Alkali-salts	95·1	97·7	96·4	2·7	7·2	9·3	8·3

Over the whole period, the average annual produce by superphosphate of lime alone, is $25\frac{5}{8}$ bushels of dressed corn, and $13\frac{3}{8}$ cwts. of straw; by the mixed alkali-salts alone, $22\frac{1}{2}$ bushels of dressed corn, and $12\frac{1}{4}$ cwts. of straw; and by the two manures together, $27\frac{1}{2}$ bushels of corn, and $14\frac{3}{8}$ cwts. of straw. The unmanured produce being 21 bushels of corn, and 12 cwts. of straw, the average annual increase is, by the superphosphate alone, $4\frac{5}{8}$ bushels of corn, and $1\frac{1}{4}$ cwt. of straw; by the mixed alkali-salts, $1\frac{1}{2}$ bushel of corn, and $\frac{1}{4}$ cwt. of straw; and by the mixture of the two, $6\frac{1}{2}$ bushels of corn, and $2\frac{1}{4}$ cwts. of straw.

Neither of these purely mineral manures has, then, sufficed to yield anything like a fair crop of barley. The mixed alkali-salts alone have given scarcely any increase at all. It was, therefore, not in an available supply of potass, soda, or magnesia, that the soil was rendered relatively deficient, either by the previous ordinary cropping, or by the continuous growth of barley. Superphosphate of lime alone gave but little, though still notably more increase than the mixed alkali-salts. It would appear, therefore, that there was, within the range of the roots, a greater relative deficiency of available phosphoric acid than of available alkalies. The mixture of the two manures, again, gave slightly more increase than either, or than both, used separately.

The explanation of the effects of these mineral manures, and of the great falling off in the produce, not only by them, but without manure, probably is, that in each case the produce has been limited by the supply of available nitrogen accumulated within the soil, whether from previous cultivation, manuring, and cropping, or by annual deposition and absorption; and that, with the increased supplies of available mineral matter near the surface, root-development has been more or less increased, possession thus acquired of a greater range of soil, and, with this, access obtained to more of its stored-up nitrogen. On this view, the "*condition*" of the soil, as distinguished from its normal or natural fertility, is at any rate so far as available nitrogen is concerned, being gradually worked out by the growth of the crop, whether without manure, or with the purely mineral manures; and it remains to be seen whether or not the point of normal annual produce has yet been reached.

There are two other plots receiving annually mineral manure alone; namely 5 O, and M; the full particulars of which will be found in the Appendix Tables. They are much smaller, and at the opposite end of the field from the other mineral-manured plots, and the results seem not altogether comparable with those of the latter, though there is less reason to suppose that they are not so with one another. Plot 5 O has received annually superphosphate of lime and sulphate of potass (that is excluding sulphates of soda and magnesia); and Plot M has received superphosphate, and sulphates of soda and magnesia (that is excluding sulphate of potass).

The mixture of superphosphate and potass-salt has given an annual average of slightly more corn, but no more straw, than the superphosphate and soda and magnesia salts, without potass. The produce by both manures has fallen off over the later as compared with the earlier years, so far as corn is concerned; but by that including potass it has done so more than by the one without it; and whilst by the manure containing potass, the produce of straw also has fallen off, that by the soda and magnesia without potass has even increased in straw during the later years. Taken over the whole period, the mixture of superphosphate and potass-salt has given annually about $1\frac{1}{2}$ bushel more corn, but only exactly the same amount of straw, as that with soda and magnesia, but without potass. The crop was, however, in both cases most miserable; in the one only $22\frac{7}{8}$, in the other only $21\frac{1}{2}$ bushels of corn, and in both only $12\frac{3}{8}$ cwts. of straw.

It may be concluded that there was in neither case any deficiency of *mineral* matter for such meagre crops; but that in the one the relatively liberal supply of potass favoured seeding tendency, and in the other the salts of soda and magnesia, whether by action on the soil, or more directly on the development of the plant itself, favoured some increase of plant, without corresponding seeding tendency. Evidence of the effects of superphosphate and potass-salts, compared with superphosphate, potass, soda, magnesia-salts will be forthcoming when the results obtained with these mixtures in conjunction with nitrogenous manures are considered.

It will be of interest to compare the effects of purely mineral manures on wheat, and on barley. The following Table (XXX.) shows the effects of the same "mixed mineral manure," used over the same period of 20 years, with the two crops. As in the case of the experiment with farmyard manure, the produce, not the increase, of the two crops is taken for illustration, and, *mutatis mutandis*, for similar reasons. But it should be further explained, that whilst in the case of the wheat plot, 8 crops, variously but upon the whole liberally manured, had already been taken, in that of the barley the period commences with the first year of the experiments.

As without manure, and with farmyard manure, so with the mixed mineral manures, barley yields considerably more grain than wheat—in fact, not far short of one-half more. On the other hand, it gives rather less straw, but of total produce (corn and straw together) considerably more than the wheat. It may be added that, although the figures and their relations would differ, more or less, if the increase instead of the produce were taken for comparison, yet the general results would be the same.

TABLE XXX.—Average Annual Produce of Wheat and of Barley by purely Mineral Manure.

MANURES PER ACRE, PER ANNUM:— 3½ Cwts. Superphosphate of Lime. 200 lbs. (1) Sulphate Potass. 100 lbs. (2) Sulphate Soda. 100 lbs. Sulphate Magnesia.	AVERAGE ANNUAL PRODUCE, &c. First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852'–71.	Second 10 Years over (or under —) First 10.
Total Corn, per Acre—lbs.				
				Per Cent.
Wheat (Plot 5) 20 years, 1852–1871	1149	987	1068	—14·1
Barley (Plot 4 O) 20 years, 1852–1871	1712	1387	1550	—19·0
Barley over (or under —) Wheat	563	400	482	
Straw (and Chaff), per Acre—lbs.				
Wheat (Plot 5) 20 years, 1852–1871	1919	1437	1678	—25·1
Barley (Plot 4 O) 20 years, 1852–1871	1805	1420	1612	—21·3
Barley over (or under —) Wheat	—114	—17	—65	
Total Produce (Corn, Straw, and Chaff), per Acre—lbs.				
Wheat (Plot 5) 20 years, 1852–1871	3068	2424	2746	—21·0
Barley (Plot 4 O) 20 years, 1852–1871	3517	2807	3162	—20·2
Barley over (or under —) Wheat	449	383	417	

(1) 300 lbs. for the first 6 years of barley, and first 7 years of wheat.
(2) 200 lbs. for the first 6 years of barley, and first 7 years of wheat.

The result itself is remarkable from several points of view. The wheat plot, although it had previously yielded 8 experimental crops, had, during that time, received considerable quantities of mineral manure and ammonia-salts, and some rape-cake also. It would be supposed, therefore, that there was more "*condition*" to work out of it than out of the barley plot. Then again, the assumed greater root-range of the autumn-sown wheat, than of the spring-sown barley, and the longer period of growth of the autumn-sown crop, would, it might be concluded, give it a greater command over the stores within the soil. Further, calculation shows that the barley crop would actually contain more nitrogen than the wheat.

Is the less result with mineral manures on wheat than on barley due to the dilution and distribution of the autumn-sown manures by the winter rains, and to their having acquired a comparatively insoluble condition, resulting in a less active root-development in the upper, and more highly nitrogenous layers of the soil, when growth commences in the spring? Is there, consequently, a more rapid exhaustion of the accumulated nitrogen within the soil by the barley than by the wheat? Or, does the pipe-draining of the wheat-field render the drainage the more free, and so cause a greater washing out of nitrogenous compounds in the winter; even from the plots where none are artificially applied? It is at any rate consistent with the supposition that there is a more rapid exhaustion of the nitrogen accumulated within the soil, by the barley than by the wheat, when each is grown without nitrogenous manure, that, according to calculation it appears probable that, both without manure, and with purely mineral manure, the barley has carried off more nitrogen from a given area than the wheat, whilst it has, under both conditions, declined more rapidly in annual produce of corn, and without manure in *total* produce also.

The general result with the purely mineral manures is—that superphosphate of lime gave more increase of barley than a mixture of salts of potass, soda, and magnesia; that neither the one nor the other, nor the mixture of all, sufficed to raise the produce to anything like a fair crop; and that, with either, the crop fell off considerably over the later years. Nevertheless, both the produce and the increase of barley by the mixed mineral manure were considerably greater than those of wheat by the same manure. It may be concluded that the exhaustion which the soil undoubtedly suffered, was not connected with a relative deficiency of any of the constituents which these mineral manures supplied. The results next to be considered will show in what the exhaustion really did consist.

Average Annual Produce by Ammonia-salts alone, or Nitrate of Soda alone.

Of the four experiments under this head, the first to be noticed are those on—

Plot 1 A with 200 lbs. of ammonia-salts per acre per annum, for 20 years, 1852-1871.

Plot 1 N with 275 lbs. nitrate of soda per acre per annum, for 19 years, 1853-1871.

200 lbs. of ammonia-salts and 275 lbs. of nitrate of soda, are estimated to supply the same amount of nitrogen, namely 41 lbs. = 50 lbs. of ammonia. But it must be noted that the plot subsequently

having nitrate received, in the first year of the twenty, 3½ cwts. of superphosphate of lime, and 300 lbs. of sulphate of potass, per acre. These mineral manures gave no increase whatever in the year of their application; but, under the exhausting process of afterwards using nitrogenous manures alone for so many years in succession, they have doubtless had considerable effect on the succeeding crops. Hence, unfortunately, the two experiments, the one with a given amount of nitrogen as ammonia-salts for 20 years, and the other with the same amount as nitrate of soda for the last 19 of the 20 years, are not strictly comparable. (Table XXXI., next page.)

In the first place, notwithstanding the great demand made on the mineral resources of the soil, by applying ammonia-salts alone year after year, there is considerably less falling off in the produce over the second as compared with the first ten years, under such treatment, than by the application of mixed mineral manure alone every year. And not only so: whilst, over the twenty years, the average annual produce was, by the mixed mineral manure only 27½ bushels of corn and 14⅜ cwts. of straw, that by the 200 lbs. of ammonia-salts alone was 32½ bushels of corn, and 18½ cwts. of straw. In other words, whilst the *increase* of produce by the mixed mineral manure alone averaged, over twenty years, only 6½ bushels of corn and 2¼ cwts. of straw, per acre per annum, that by this comparatively small quantity of ammonia-salts alone averaged, over the same period, 11½ bushels of corn, and 6⅜ cwts. of straw.

Comparing the result by ammonia-salts for 20 years, with that by the same quantity of nitrogen as nitrate of soda for 19 years, the average annual produce and increase are 5¼ bushels of corn, and 4⅝ cwts. of straw, more by the nitrate than by the ammonia-salts.

It is obvious that, owing to the greater solubility, and more rapid distribution in the soil and subsoil, of the nitrate or its products of decomposition, it will be the more liable to loss by drainage when there is an excess of rain. On the other hand, as already referred to (p. 56), the subsoil in its case becomes more disintegrated, therefore more porous, more retentive of moisture in a favourable condition, and more permeable by the roots. It is, probably, in part due to this action that the effects of a given amount of nitrogen as nitrate of soda increase from year to year compared with those of an equivalent application as ammonia-salts. How much of the greater effect of the nitrate in the experiment in question may be due to this action, and how much to the supply of mineral manure to the nitrated plot in the first year, it is impossible to determine.

On the latter point it may be mentioned, that the amounts of

TABLE XXXI.—Average Annual Produce and Increase of Barley by 200 lbs. of Ammonia-salts alone, or 275 lbs. of Nitrate of Soda alone.

Plots.	MANURES PER ACRE, PER ANNUM.	AVERAGE ANNUAL PRODUCE, &c. First Half of Period. (1)	Second Half of Period.	Total Period. (1)	Second Period (over or under –) First Period.	AVERAGE ANNUAL INCREASE OVER (or under –) UNMANURED (Plots 1 O and 6–1.) First Half of Period. (1)	Second Half of Period.	Total Period. (1)
	Dressed Corn, per Acre—Bushels.							
					Per Cent.			
1 A	200 lbs. Ammonia-salts; 20 years, 1852–1871 ..	$33\frac{5}{8}$	$31\frac{3}{8}$	$32\frac{1}{2}$	– 6·7	$9\frac{7}{8}$	$13\frac{1}{8}$	$11\frac{1}{2}$
1 N	275 lbs. Nitrate Soda; 19 years, 1853–1871	$37\frac{5}{8}$	$37\frac{1}{8}$	$37\frac{3}{8}$	– 1·3	$14\frac{3}{8}$	$18\frac{5}{8}$	$16\frac{3}{4}$
	Total Corn, per Acre—lbs.							
1 A	200 lbs. Ammonia-salts; 20 years, 1852–1871 ..	1908	1771	1840	– 7·2	560	744	652
1 N	275 lbs. Nitrate Soda; 19 years, 1853–1871	2124	2108	2116	– 0·8	806	1081	950
	Straw (and Chaff), per Acre—Cwts.							
1 A	200 lbs. Ammonia-salts; 20 years, 1852–1871 ..	$19\frac{3}{4}$	$17\frac{3}{8}$	$18\frac{1}{2}$	–12·0	6	$6\frac{7}{8}$	$6\frac{3}{8}$
1 N	275 lbs Nitrate Soda; 19 years, 1853–1871	$23\frac{3}{8}$	$22\frac{1}{2}$	$22\frac{7}{8}$	– 3·7	10	$11\frac{3}{4}$	$10\frac{7}{8}$
	Total Produce (Corn, Straw, and Chaff), per Acre—lbs.							
1 A	200 lbs. Ammonia-salts; 20 years, 1852–1871 ..	4119	3719	3919	– 9·7	1234	1519	1376
1 N	275 lbs. Nitrate Soda; 19 years, 1853–1871	4745	4628	4683	– 2·5	1928	2428	2191
	Weight per Bushel of Dressed Corn—lbs.							
1 A	200 lbs. Ammonia-salts; 20 years, 1852–1871 ..	51·2	53·0	52·1	3·5	–0·3	–0·3	–0·3
1 N	275 lbs. Nitrate Soda; 19 years, 1853–1871	51·6	53·7	52·7	4·1	0·1	0·4	0·3
	Corn to 100 Straw.							
1 A	200 lbs. Ammonia-salts; 20 years, 1852–1871 ..	86·4	91·9	89 2	6·4	–1·5	3·5	1·1
1 N	275 lbs. Nitrate Soda; 19 years, 1853–1871	81 3	86·0	83·7	5·8	–6·9	–2·4	–4·5

(1) **For the Nitrate plot (1 N), the averages for the first period are for only 9 years, and for the total pericd for only 19 years.**

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phosphoric acid and potass applied in the first year, but which gave no increase in that year, were sufficient, if still present and available, to supply those constituents for more than the excess of corn and straw obtained on the nitrate, as compared with the ammonia-plot. Further, the experiments with wheat have afforded abundant evidence, that phosphates and potass-salts previously applied, have been effective for 20 years or more, when nitrogenous manures have been afterwards supplied, to work them out, so to speak. There can be little doubt, indeed, that part, at any rate, of the greater effect of the nitrate in the experiment in question, was really due to the supply of mineral constituents in the first year.

The results next to be considered show the effects of double the above amounts of ammonia-salts alone, or nitrate of soda alone, but applied for a few years only as under:—

Plot 1. A. A:—

6 years, 1852-1857, 400 lbs. ammonia-salts, per acre, per annum.

Plot 2. N:—

1 year, 1852, $3\frac{1}{2}$ cwts. superphosphate, 300 lbs. sulphate potass;

5 years, 1853-1857, 550 lbs. nitrate of soda.

Thus, as in the previous comparison, the two plots received corresponding amounts of nitrogen as ammonia-salts, and as nitrate of soda, respectively, for a series of years; but whilst the ammonia plot received the double dressing of ammonia-salts, in the first as well as the succeeding 5 years, the nitrate plot received phosphates and potass without nitrate in the first year, and the double quantity of nitrate in the succeeding 5 years.

Table XXXII. (see next page) shows the produce obtained, and also the increase, both over the unmanured produce, and over that by the smaller amounts of ammonia-salts, or nitrate, in the corresponding years.

Thus, there is an average annual produce of 46 bushels of corn, and $28\frac{1}{2}$ cwts. of straw, by the application of 400 lbs. of ammonia-salts alone for 6 years; also of 48 bushels of corn, and $31\frac{1}{2}$ cwts. of straw, by the same amount of nitrogen as nitrate of soda alone for 5 years (but succeeding a dressing of superphosphate and sulphate of potass). The produce by the double amount of ammonia-salts alone represents an average annual increase over the unmanured produce of $17\frac{7}{8}$ bushels of corn, and $12\frac{1}{4}$ cwts. of straw; and of $7\frac{3}{8}$ bushels of corn, and $5\frac{7}{8}$ cwts. of straw over that by half the quantity of ammonia-salts for the same period. In like manner the produce by the double amount of nitrate of soda alone, represents an annual total increase of $19\frac{7}{8}$

bushels of corn, and 15⅜ cwts. of straw; and an increase over the produce by the single amount of nitrate, of 5⅞ bushels of corn, and 6 cwts. of straw.

TABLE XXXII.—Average Annual Produce and Increase by 400 lbs. Ammonia salts alone, or 550 lbs. Nitrate of Soda alone.

Plots.	MANURES PER ACRE, PER ANNUM.	Average Annual Produce.	AVERAGE ANNUAL INCREASE. Over Unmanured (Plots 1 O and 6–1.)	AVERAGE ANNUAL INCREASE. 1 AA over 1 A. — 2 N over 1 N.
	Dressed Corn per Acre—Bushels.			
1 AA	400 lbs Ammonia-salts; 6 years, 1852–1857	46	17⅞	7⅜
2 N	550 lbs. Nitrate of Soda; 5 years, 1853–1857	48	19⅞	5⅞
	Total Corn per Acre—lbs.			
1 AA	400 lbs. Ammonia-salts; 6 years, 1852–1857	2603	1005	412
2 N	550 lbs. Nitrate of Soda; 5 years, 1853–1857	2666	1070	302
	Straw (and Chaff) per Acre—Cwts.			
1 AA	400 lbs. Ammonia-salts; 6 years, 1852–1857	28½	12¼	5⅞
2 N	550 lbs. Nitrate of Soda; 5 years, 1853–1857	31½	15⅜	6
	Total Produce (Corn, Straw, and Chaff) per Acre—lbs.			
1 AA	400 lbs. Ammonia-salts; 6 years, 1852–1857	5794	2371	1066
2 N	550 lbs. Nitrate of Soda; 5 years, 1853–1857	6198	2794	972
	Weight per Bushel of Dressed Corn—lbs.			
1 AA	400 lbs. Ammonia-salts; 6 years, 1852–1857	50·7	– 1·0	–0·8
2 N	550 lbs. Nitrate of Soda; 5 years, 1853–1857	50·9	– 0·7	–1·0
	Corn to 100 Straw.			
1 AA	400 lbs. Ammonia-salts; 6 years, 1852–1857	82·5	– 5·7	–4·4
2 N	550 lbs. Nitrate of Soda; 5 years, 1853–1857	75·4	–13·4	–7·4

We have here, then, by the application of ammonia-salts alone, or of nitrate of soda alone, an average annual produce, over 5 or

6 consecutive years, of 46 or 48 bushels of barley; or considerably more than the amount assumed (p. 9) to be a good produce under ordinary rotation and cultivation. These amounts are also fully one-third more than was obtained by purely mineral manure over the same period.

It was found that these double dressings were too heavy, the crops frequently being much laid; and hence, after the first 6 years of the experiments, the quantities were reduced to one-half, that is, to the same as on plots 1 A and 1 N. For many subsequent years, however, the plots previously receiving the larger amounts, whether alone, or with mineral manure (as presently to be noticed), continued to yield more produce than the plots receiving the smaller quantity from the commencement. But as the effects of the unexhausted residue from previous manuring upon succeeding crops will be considered separately and in detail in Section IV. no more need be said on the point in this place.

It would be interesting to compare the effects of purely nitrogenous manures on wheat and on barley; but as the experiments with such manures on the two crops are not as parallel as is desirable, either as regards the previous history of the plots, the quantities applied, or the periods and duration of the experiments, the comparison might be misleading unless given with much explanation and qualification. The omission is, however, of the less consequence, as we shall be enabled to compare the effects on the two crops of a mixture of ammonia-salts and mineral manure together, which in fact is of much greater practical importance.

The practice of growing barley for so many years in succession on the same land by any means whatever, is not, it is true, recommended for adoption in practical agriculture; and still less desirable would it be so to grow it by means of ammonia-salts alone, or nitrate of soda alone. But the extraordinary results which have been recorded are not the less instructive and important, or of less practical value, on that account.

It is of no little interest to know, that on a soil, consisting of a somewhat heavy loam with a clayey subsoil, and of only moderate corn-yielding capabilities, purely mineral manures will not yield anything like a fair crop of wheat or barley; but that, on the same soil, a comparatively small quantity of purely nitrogenous manures has yielded, for twenty years in succession, not much less barley than the average crop of the country; and that a larger amount has given, over 6 consecutive seasons, considerably more than an average crop. This is knowledge acquired of the available mineral resources of such a soil, which analysis would not have afforded; and which supplies, if not examples for exact imitation, at any rate a very sound basis for deduction in regard to actual practice.

Average annual Produce by Ammonia-salts or Nitrate of Soda, with mineral Manure in addition.

The first set of experiments to be noticed here, includes four plots, each of which has received 200 lbs. ammonia-salts per acre per annum, throughout the twenty years, but each with a different mineral manure in addition. The mineral manures, here used in admixture with nitrogenous manures, are the same as in the experiments with purely mineral manures, which have already been considered. As only much abbreviated descriptions of the manures can be given in the Table (see next page), they are described in full below:—

Plot 2 A—200 lbs. Ammonia-salts, and 3½ cwts. Superphosphate of Lime.

Plot 3 A—200 lbs. Ammonia-salts, and mixed Alkali-salts, —namely, a mixture of 200 lbs.* Sulphate Potass, 100 lbs.† Sulphate Soda, 100 lbs. Sulphate Magnesia.

Plot 4 A—200 lbs. Ammonia-salts, 3½ cwts. Superphosphate, and the "mixed Alkali-salts."

Plot 5 A—200 lbs. Ammonia-salts, 3½ cwts. Superphosphate, and 200 lbs.* Sulphate Potass.

The produce is averaged over the first 10, the second 10, and the 20 years. The increase is calculated over the produce without manure, and also, in each case, over that by the corresponding mineral manure without ammonia-salts;—that is 2 A over 2 O, 3 A over 3 O, 4 A over 4 O, and 5 A over 5 O.

It is remarkable that, instead of, as without manure, with purely mineral manure, or with purely nitrogenous manure, a considerable falling off in the second compared with the first half of the total period, there is, with ammonia-salts and mineral manure together (though without silica), in each case a more or less increased produce of corn over the second compared with the first 10 years. On the other hand, there is in two out of the four cases a slight, and in a third a more considerable, deficiency of straw over the later period; and it is only in that one instance that there is any material diminution in quantity of total produce, and then little more than 5 per cent.

So far as quality of the produce is concerned, both weight per bushel of dressed corn, and proportion of corn to straw, are in every case higher over the second than the first 10 years.

It has been concluded (pp. 78–9) that the second period was, so far as the seasons themselves are concerned, the more favourable for the production of corn, but the less for that of straw and total produce.

* 300 lbs. the first six years, 200 lbs. afterwards.
† 200 lbs. the first six years, 100 lbs. afterwards.

TABLE XXXIII.—Average Annual Produce and Increase by 200 lbs. Ammonia-salts, and Mineral Manure.

Twenty years, 1852–1871.

Plots.	MANURES PER ACRE, PER ANNUM. 200 lbs. Ammonia-salts, and Mineral Manures as under—	AVERAGE ANNUAL PRODUCE, &c. First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total 20 Years, 1852–'71.	Second 10 Years over (or under –) First 10.	AVERAGE ANNUAL INCREASE, 20 YEARS. Over Mean Unmanured.	Over corresponding Mineral Manures.
	Dressed Corn per Acre—Bushels.				Per Cent.		
2 A	Superphosphate ..	45¾	48½	47⅛	6·0	26⅛	21½
3 A	Mixed Alkali-salts ..	35	35⅛	35⅛	0·4	14⅛	12⅝
4 A	Superphosphate and Mixed Alkali-salts	46¼	46½	46⅜	0·5	25⅜	18⅞
5 A	Superphosphate and Sulphate Potass ..	43½	44⅞	44⅛	3·2	23⅛	21¼
	Total Corn per Acre—lbs.						
2 A	Superphosphate ..	2563	2762	2662	7·8	1474	1223
3 A	Mixed Alkali-salts ..	1989	1995	1992	0·3	804	724
4 A	Superphosphate and Mixed Alkali-salts	2593	2668	2630	2·9	1442	1080
5 A	Superphosphate and Sulphate Potass ..	2426	2584	2505	6·5	1317	1212
	Straw (and Chaff) per Acre—Cwts.						
2 A	Superphosphate ..	27⅞	27⅓	27⅝	–1·5	15½	14¼
3 A	Mixed Alkali-salts ..	21⅞	19¾	20¾	–9·8	8⅝	8½
4 A	Superphosphate and Mixed Alkali-salts	28⅞	28	28½	–2·9	16⅜	14⅛
5 A	Superphosphate and Sulphate Potass ..	27⅞	28¼	28	1·5	15⅞	15⅝
	Total Produce (Corn, Straw, and Chaff) per Acre—lbs.						
2 A	Superphosphate ..	5683	5837	5760	2·7	3218	2829
3 A	Mixed Alkali-salts ..	4434	4200	4317	–5·3	1775	1676
4 A	Superphosphate and Mixed Alkali-salts	5827	5808	5817	–0·3	3275	2655
5 A	Superphosphate and Sulphate Potass ..	5542	5747	5644	3·7	3102	2962
	Weight per Bushel of Dressed Corn—lbs.						
2 A	Superphosphate ..	51·8	55·1	53·5	6·4	1·1	0·3
3 A	Mixed Alkali-salts ..	51·5	54·1	52·8	5·0	0·4	–0·2
4 A	Superphosphate and Mixed Alkali-salts	52·2	55·7	54·0	6·7	1·6	0·6
5 A	Superphosphate and Sulphate Potass ..	51·9	55·7	53·8	7·3	1·4	0·3
	Corn to 100 Straw.						
2 A	Superphosphate ..	81·9	91·8	86·8	12·1	–1·3	–10·3
3 A	Mixed Alkali-salts ..	81·4	91·3	86·3	12·2	–1·8	– 6·1
4 A	Superphosphate and Mixed Alkali-salts	79·9	86·4	83·2	8·1	–4·9	–13·2
5 A	Superphosphate and Sulphate Potass ..	77·8	83·1	80·4	6·8	–7·7	–15·8

The evidence taken as a whole, therefore, gives no indication of any deterioration in either the quantity or the quality of the produce as the result of the continuous growth of the crop, provided the necessary constituents are supplied by manure.

It is seen that whilst the average annual produce over the twenty years is, with ammonia-salts and superphosphate of lime $47\frac{1}{8}$ bushels of dressed corn and $27\frac{5}{8}$ cwts. of straw, with the same quantity of ammonia-salts and a mixture of sulphates of potass, soda, and magnesia, it is only $35\frac{1}{8}$ bushels of corn, and only $20\frac{3}{4}$ cwts. of straw. Even with the ammonia-salts and both the superphosphate and the "mixed alkali-salts," it is only $46\frac{3}{8}$ bushels of corn, and $28\frac{1}{2}$ cwts. of straw; or rather less corn, though rather more straw, and total produce, than with the ammonia-salts and superphosphate without the salts of potass, soda, and magnesia. It is further remarkable that the yield of corn has increased more over the later period where the superphosphate was used without, than where in conjunction with the mixed alkali-salts. The details show, however, that the produce, at any rate of straw, where the mixed alkali-salts and the superphosphate are used together, has been of late years somewhat gaining upon that where the superphosphate is used alone.

It may be mentioned, though not shown in the Table, that the *increase* over the unmanured, or over the corresponding mineral manured produce, is much greater over the second period compared with the first, than is the augmentation of the *actual produce* itself. This is explained by the fact that the produce without manure, or by the mineral manures alone, was much the less over the later period, and hence, though there was much the same actual amount of produce over the two periods when ammonia was also used, still the increase over that without ammonia is much the greater.

Over the whole period of twenty years the average annual increase of produce due to the combined action of mineral and nitrogenous manures is, with the ammonia-salts and superphosphate, $26\frac{1}{8}$ bushels of corn and $15\frac{1}{2}$ cwts. of straw; with the same and the mixed alkali-salts in addition, $25\frac{3}{8}$ bushels of corn and $16\frac{3}{8}$ cwts. of straw; with the same and sulphate of potass (without soda and magnesia) $23\frac{1}{8}$ bushels of corn, and $15\frac{7}{8}$ cwts. of straw; but with the ammonia-salts and salts of potass, soda and magnesia (without superphosphate) only $14\frac{1}{8}$ bushels of corn and $8\frac{5}{8}$ cwts. of straw. Or, if the increase be reckoned over the produce by the corresponding mineral manure without ammonia, in which case it is the increase due to the ammonia itself that is more nearly represented, it is, when used with superphosphate of lime $21\frac{1}{2}$ bushels of corn, and $14\frac{1}{4}$ cwts. of straw; when with superphosphate and the mixed alkali-salts 18⅞ bushels of corn, and 14⅛ cwts. of straw; when with the superphosphate and sulphate of potass 21¼ bushels of corn, and 15⅝ cwts. of straw; but when with the mixed alkali-salts without superphosphate, only 12⅝ bushels of corn and 8½ cwts. of straw.

Thus, the effect of a given amount of ammonia is seen to differ very greatly according to the character of the mineral constituents supplied with it. The results clearly show, what common experience also teaches, how effective a manure for barley is superphosphate of lime, provided only there be also a sufficient available supply of nitrogen within the soil. It is, however, as a rule, much less effective with winter-sown than with spring-sown corn-crops; the latter, with their short period of growth, and relatively greater dependence on root-development near the surface, requiring more liberal supplies within a limited range of soil.

Considering the characters of the soil, and the results obtained with other crops, to say nothing of general practical experience, it is only what would be anticipated, that the addition to the ammonia-salts of superphosphate of lime would be much more effective than that of salts of potass, soda, and magnesia; but it is hardly what would be expected that, over twenty years in succession, the soil would yield an average of even rather more corn, only ⅞ cwt. less straw, and only 57 lbs. less total produce, with ammonia-salts and superphosphate, than with the ammonia-salts, superphosphate, and the mixed alkali-salts together. The illustration is a striking one of the potass-yielding capabilities of such a soil. As already intimated, there are symptoms of a slight change during the last few years; but the fact is of great practical and scientific interest, that by ammonia-salts and superphosphate of lime, without potass or other bases, considerably more than the average barley crop of the country has been obtained for twenty years in succession.

Table XXXIV. (next page) shows the produce and increase obtained by the same mineral manures as those employed in three of the four experiments last considered, but, in each case, with double the amount of ammonia-salts; namely, 400 lbs. per acre per annum, used, however, for only the first six years of the twenty. The increase is given over the produce without manure, over that by the corresponding mineral manures without ammonia, and over that by the corresponding mineral manure with only 200 lbs. of ammonia-salts.

It is obvious that, with an average annual produce of 46 or 47 bushels of barley, over twenty years, by the mineral manures and 200 lbs. of ammonia-salts per acre, the limit of the ripening capabilities of the seasons must have been nearly reached.

TABLE XXXIV.—Average Annual Produce and Increase by 400 lbs. Ammonia-salts, and Mineral Manure.

Six Years, 1852–1857.

Plots.	MANURES PER ACRE, PER ANNUM. 400 lbs. Ammonia-salts, and Mineral Manures as under.	Average Annual Produce. 6 Years, 1852–'57.	AVERAGE ANNUAL INCREASE, 6 YEARS. Over Mean Unmanured.	Over corresponding Mineral Manures.	Over corresponding Mineral Manures and 200 lbs. Ammonia-salts.
	Dressed Corn per Acre—Bushels.				
2 AA	Superphosphate of Lime	49⅝	21½	18	4⅛
3 AA	Mixed Alkali-salts	42⅞	14¾	14	3¼
4 AA	Superphos. and Mixed Alkali-salts	50¾	22⅝	16¼	4½
	Total Corn per Acre—lbs.				
2 AA	Superphosphate of Lime	2775	1177	1027	230
3 AA	Mixed Alkali-salts	2441	843	814	169
4 AA	Superphos. and Mixed Alkali-salts	2801	1203	887	205
	Straw (and Chaff) per Acre—Cwts.				
2 AA	Superphosphate of Lime	34	17¾	17½	5⅝
3 AA	Mixed Alkali-salts	29⅝	13⅜	13⅝	4¾
4 AA	Superphos. and Mixed Alkali-salts	36⅜	20⅛	18⅜	7¼
	Total Produce (Corn, Straw, and Chaff) per Acre—lbs.				
2 AA	Superphosphate of Lime	6590	3170	2996	872
3 AA	Mixed Alkali-salts	5753	2333	2330	697
4 AA	Superphos. and Mixed Alkali-salts	6874	3454	2948	1011
	Weight per Bushel of Dressed Corn—lbs.				
2 AA	Superphosphate of Lime	50·5	− 1·2	− 1·3	−1·0
3 AA	Mixed Alkali-salts	50·8	− 0·9	− 1·2	−1·0
4 AA	Superphos. and Mixed Alkali-salts	50·4	− 1·3	− 1·5	−1·6
	Corn to 100 Straw.				
2 AA	Superphosphate of Lime	73·1	−15·1	−21·8	−6·9
3 AA	Mixed Alkali-salts	74·1	−14·1	−16·9	−8·0
4 AA	Superphos. and Mixed Alkali-salts	69·4	−18·8	−26·5	−9·9

Indeed, the double amount of ammonia-salts was found, even when used in conjunction with mineral manure, to be quite excessive, the crops being generally laid; and hence, after six years' trial, the extra application was discontinued. Under these circumstances any great increase of produce by 400 lbs. compared with 200 lbs. of ammonia-salts could not be expected. Still, as the last column of the Table shows, the second increment of 200 lbs. did, under favourable conditions of mineral manuring, raise the produce by more than 4 bushels of grain, and by from $5\frac{1}{2}$ to $7\frac{1}{4}$ cwts. of straw; bringing it up, with superphosphate of lime, to $49\frac{5}{8}$ bushels of corn, and 34 cwts. of straw; and with superphosphate and the "mixed alkali-salts" together, to $50\frac{3}{4}$ bushels of corn, and $36\frac{3}{8}$ cwts. of straw.

There is proportionally much more increase of straw than of corn, especially when both the superphosphate and mixed alkali-salts were used. There is also a lower weight per bushel of dressed corn, and a much lower proportion of corn to straw, than with the corresponding mineral manures, either alone, or with the smaller quantity of ammonia-salts. It is clear, therefore, that the extra quantity of ammonia-salts considerably increased the luxuriance; but that the amount of plant produced was more than could, under the conditions of the seasons, form a fair proportion of corn, and ripen well.

Although the second increment of 200 lbs. of ammonia-salts, has thus not yielded anything like the same amount of increase as the first, in the seasons of the application, it will afterwards be seen (Section IV.) that there was a considerable residue of nitrogen left within the soil, which remained available for future crops through many succeeding seasons.

After the six years of the double application, the amount of ammonia-salts was reduced to 200 lbs. per acre per annum, and the experiment continued for ten consecutive seasons. From that time, however, an amount of nitrate of soda (275 lbs.) containing the same amount of nitrogen as 200 lbs. of ammonia-salts, was substituted for the latter; and the results obtained during the four years of the experiment which have so far elapsed, are given in Table XXXV. (next page.)

It is remarkable that the average produce is almost identical by the nitrate alone, and by the nitrate and "mixed alkali-salts" together. Though much higher, it is again almost identical by the nitrate and superphosphate, and by the nitrate, superphosphate, and "mixed alkali-salts." The little effect, hitherto, of the potass, soda, and magnesia-salts is here again illustrated. The last column shows that, over the four seasons in question, the nitrate gave, under each of the conditions of mineral manuring, both more corn and more straw than the corresponding amount of ammonia-salts. In what degree, however, this difference should be attributed to a greater effect of the nitrate, and in what to a still effective residue from the excessive supply of ammonia-salts

TABLE XXXV.—Average Annual Produce and Increase by 275 lbs. Nitrate of Soda per Acre per Annum, alone, and with Mineral Manures.

Four Years, 1868–1871.

Plots.	MANURES PER ACRE, PER ANNUM. 275 lbs. Nitrate of Soda, without Mineral Manure, and with Mineral Manures as under.	Average Annual Produce. 4 Years, **1868–'71.**	AVERAGE ANNUAL INCREASE. Over Mean Unmanured.	Over corresponding Mineral Manures.	Over corresponding Mineral Manures, and 200 lbs. Ammonia-salts.
	Dressed Corn per Acre—Bushels.				
1 AA	Without Mineral Manure	32	16¼	16⅝	3⅞
2 AA	Superphosphate of Lime	46¼	30½	26¾	3⅛
3 AA	"Mixed Alkali-salts"	32½	16¾	15⅛	¼
4 AA	Superphos. and Mixed Alkali-salts	46½	30¾	25⅝	4⅜
	Total Corn per Acre—lbs.				
1 AA	Without Mineral Manure	1788	903	929	187
2 AA	Superphosphate of Lime	2691	1806	1577	187
3 AA	"Mixed Alkali-salts"	1852	967	858	11
4 AA	Superphos. and Mixed Alkali-salts	2692	1807	1498	244
	Straw (and Chaff) per Acre—Cwts.				
1 AA	Without Mineral Manure	20⅛	9⅞	10	3⅝
2 AA	Superphosphate of Lime	28⅛	17⅞	18⅛	3¾
3 AA	"Mixed Alkali-salts"	21¼	11	11⅜	2¼
4 AA	Superphos. and Mixed Alkali-salts	28⅝	18⅜	17	2
	Total Produce (Corn, Straw, and Chaff) per Acre—lbs.				
1 AA	Without Mineral Manure	4047	2023	2061	596
2 AA	Superphosphate of Lime	5843	3819	3611	614
3 AA	"Mixed Alkali-salts"	4238	2214	2142	268
4 AA	Superphos. and Mixed Alkali-salts	5901	3877	3411	475
	Weight per Bushel of Dressed Corn—lbs.				
1 AA	Without Mineral Manure	53·9	0·1	0·3	−0·1
2 AA	Superphosphate of Lime	56·4	2·6	1·5	0·5
3 AA	"Mixed Alkali-salts"	54·4	0·6	−0·6	−0·8
4 AA	Superphos. and Mixed Alkali-salts	56·6	2·8	1·3	−0·1
	Corn to 100 Straw.				
1 AA	Without Mineral Manure	80·6	0·8	1·6	−7·7
2 AA	Superphosphate of Lime	87·9	8·1	−12·5	−7·4
3 AA	"Mixed Alkali-salts"	78·4	−1·4	−11·9	−9·6
4 AA	Superphos. and Mixed Alkali-salts	89·5	9·7	− 3·1	4·5

during the first 6 years, it is not possible to determine. Further comments on the results at present would, therefore, be premature.

It will be more instructive to compare the results obtained by the mixture of mineral and nitrogenous manure on wheat and on barley respectively. The first comparison will be between the effects of the same amounts of superphosphate of lime, and sulphates of potass, soda, and magnesia, and 200 lbs. of ammonia per acre per annum, for 20 consecutive seasons, with each crop. Table XXXVI. shows the result; and as in other cases the produce per acre, and not the increase, is taken for illustration.

TABLE XXXVI.—Average Annual Produce of Wheat and of Barley by Mixed Mineral Manure, and 200 lbs. Ammonia-salts per Acre per Annum.

MANURES PER ACRE, PER ANNUM:— 3½ cwts. Superphosphate of Lime. 200 lbs. (1) Sulphate of Potass. 100 lbs. (2) Sulphate of Soda. 100 lbs. Sulphate of Magnesia. 200 lbs. Ammonia-salts.	Average Annual Produce, &c.			
	First 10 Years, **1852–'61.**	Second 10 Years, **1862–'71.**	Total Period, 20 Years, **1852–'71.**	Second 10 Years over (or under –) First 10.
Total Corn, per Acre.				
	lbs.	lbs.	lbs.	Per Cent.
Wheat (Plot 6), 20 years, 1852–1871	1697	1639	1668	– 3·4
Barley (Plot 4 A), 20 years, 1852–1871	2593	2668	2630	2·9
Barley over (or under –) wheat	896	1029	962	
Straw (and Chaff), per Acre.				
Wheat (Plot 6), 20 years, 1852–1871	2946	2554	2750	–13·3
Barley (Plot 4 A), 20 years, 1852–1871	3234	3139	3187	– 2·9
Barley over (or under –) wheat	288	585	437	
Total Produce (Corn, Straw, and Chaff), per Acre.				
Wheat (Plot 6), 20 years, 1852–1871	4643	4193	4418	– 9·7
Barley (Plot 4 A), 20 years, 1852–1871	5827	5808	5817	– 0·3
Barley over (or under –) wheat	1184	1615	1399	

(1) 300 lbs. the first 7 years of wheat, and 6 years of barley; 200 lbs. afterwards.
(2) 200 lbs. the first 7 years of wheat, and 6 years of barley; 100 lbs. afterwards.

For the period of 20 years included in the comparison, the manuring was, with a quite immaterial exception explained in the foot-notes, identical for the two crops. But whilst in the case of the barley, the period commences with the first year of the experiments, in that of the wheat 8 experimental crops had already been taken. During that period, however, large quantities of superphosphate of lime, and potass, soda, and magnesia-salts had been applied, as well as liberal dressings of ammonia-salts. It would hardly be concluded, therefore, that the plot had suffered in wheat-growing condition by its previous treatment. Still, though the quantity of wheat-grain averages nearly the same over the two periods, that of the straw and total produce falls off considerably during the latter half of the 20 years. On the other hand, with the barley the quantity of corn is slightly higher, that of straw slightly lower, and that of total produce almost identical, over the two halves of the total period.

It is possible, therefore, that the previous history of the plots may be somewhat to the detriment of the results with wheat; but it is not probable that it has had much adverse influence.

Taking the results as they stand, the barley gives, with exactly the same manure over 20 years, an average annual produce of more than one-half more corn, more than one-sixth more straw, and about 1400 lbs. more total produce (corn and straw together) than the wheat. If, instead of the acreage produce, the increase over that by the same mineral manures without ammonia be taken, the general result is the same; namely, a great deficiency of corn, of straw, and of total produce, of wheat compared with barley, by the same manuring. How is this to be explained?

In reference to this point attention may here be recalled to the facts—that whilst the wheat is autumn-sown and autumn-manured, the barley is both spring-sown and spring-manured; and that when ammonia-salts are sown in the autumn, the winter drainage carries with it large amounts of the nitrogen of the ammonia-salts in the form of nitrates. The probable extent of the loss that may thus arise, will be considered in Section IV. It must suffice here, therefore, to state in general terms that existing evidence leads to the conclusion that it may be very considerable.

The difference of result obtained with wheat and with barley is again illustrated, under somewhat different conditions, in Table XXXVII. (see next page). The comparison is between the effects of the "mixed mineral manure" and 400 lbs. of ammonia-salts, annually applied to the two crops. For wheat the produce is averaged over 20 years (1852-'71) of the treatment, and also over the first 6 years only, those being the seasons in which the same experiment was made with the barley.

In all previous comparisons between wheat and barley the quantity of *produce per acre* has been taken, and not the *increase* of produce over that without manure, or, as the case may be, the increase by mineral manure and ammonia-salts over that by mineral manure without ammonia. It has, however, been remarked that, although the figures would be different, the general result would be the same, whether produce or increase were compared. It would not be so in the case of the experiments now under consideration. Hence, the Table has been arranged to show the comparison, both between the produce per acre, and the increase of produce by the mineral manure and 400 lbs. of ammonia-salts, over that by the corresponding mineral manure alone.

TABLE XXXVII.—Average Annual Produce and Increase of Wheat and of Barley by Mixed Mineral Manure, and 400 lbs. Ammonia-salts per Acre per Annum.

MANURES PER ACRE, PER ANNUM— 3½ Cwts. Superphosphate of Lime. 300 lbs. (1) Sulphate of Potass. 200 lbs. (2) Sulphate of Soda. 100 lbs. Sulphate of Magnesia. 400 lbs. Ammonia-salts.	AVERAGE ANNUAL PRODUCE PER ACRE.		Mineral Manure and Ammonia-salts over Mineral alone.	Barley over (or under –) Wheat.	
	Mineral Manure and 400 lbs. Ammonia-salts.	Mineral Manure alone.		Produce.	Increase.
Total Corn, per Acre.					
	lbs.	lbs.	lbs.	lbs.	lbs.
Wheat (Plot 7), 20 years, 1852–1871 ..	2228	1068	1160		
Wheat (Plot 7), 6 years, 1852–1857 ..	2195	1171	1024	606	–137
Barley (Plot 4 AA), 6 years, 1852–1857	2801	1914	887		
Straw (and Chaff), per Acre.					
Wheat (Plot 7), 20 years, 1852–1871 ..	3959	1678	2281		
Wheat (Plot 7), 6 years, 1852–1857 ..	4233	2012	2221	–160	–160
Barley (Plot 4 AA), 6 years, 1852–1857	4073	2012	2061		
Total Produce (Corn, Straw, and Chaff), per Acre.					
Wheat (Plot 7), 20 years, 1852–1871 ..	6187	2746	3441		
Wheat (Plot 7), 6 years, 1852–1857 ..	6428	3183	3245	446	–297
Barley (Plot 4 AA), 6 years, 1852–1857	6874	3926	2948		

(1) Only 200 lbs. after the first 7 years of wheat, and 6 of barley.
(2) Only 100 lbs. after the first 7 years of wheat, and 6 of barley.

Before directing attention to the results themselves, it should be premised that, as in the last experiments quoted, the wheat plot had grown 8 crops, liberally dressed with artificial manures, prior to the period to which the figures refer; but the results with barley commence with the first year of the experiments, and the application of 400 lbs. of ammonia-salts to that crop was only continued for the 6 years referred to. To the wheat, however, the application has been continued up to the present time; and, over 20 years, it has yielded an average of more corn, though less straw and total produce, than over the first 6 years. It would be concluded, therefore, that the wheat plot was not unduly exhausted at the commencement; and that the comparison between the two crops over the first 6 years would, probably, be but little open to objection on the score of difference in previous condition of the land.

Taking first the *produce per acre* of the two crops, there is, as with the smaller quantity of ammonia-salts, considerably more barley-grain than wheat-grain; but, on the other hand, less barley straw; and an annual average of only 446 lbs. more total produce (corn and straw) of barley than of wheat, instead of nearly 1400 lbs., as when the smaller quantity of ammonia-salts was employed. This difference of result is doubtless due to the proportionally much less increase of barley for a given amount of ammonia in manure with the larger than with the smaller supply of ammonia-salts. The probability is that, in the case of the autumn-sowing for the wheat, the distribution, the state of combination, and the loss by drainage are such, that the quantity of the supplied nitrogen remaining available within a given range of soil when active growth commences in the spring is not excessive, and does not induce over luxuriance; whereas, the same amount applied in the spring for the barley, being less subject to either rapid distribution or drainage, induces too much luxuriance, and, consequently, leads to the laying of the crop, and to reduced eventual productiveness.

The less difference between the produce of wheat and of barley when the larger quantity of ammonia-salts is applied, is, therefore, due, in great measure, to a proportionally less effect on the barley. Nevertheless, the fact of a less amount of produce per acre from a given amount of mineral manure and ammonia-salts applied in the autumn for wheat, than from the same amount applied in the spring for barley, is again clearly illustrated.

If, however, the *increase* of produce with ammonia over that without it be taken as the basis of illustration, the result is different. Thus, instead of an annual average of 446 lbs. more total produce (corn and straw together) of barley than of wheat, there is of *increase* of produce by the mineral manure and 400 lbs. of ammonia-salts over that by the mineral manure alone, less in the case of the barley than of the wheat. The average annual deficiency is 137 lbs. of corn, and 160 lbs. of straw, or 297 lbs. of total produce (corn and straw together). This difference is accounted for by the fact that there is an average of 743 lbs. more total produce of barley than of wheat by the mineral manure alone; there is, therefore, so much more to be deducted from the produce by the mineral manure and the ammonia-salts together; leaving, of course, so much less to be reckoned as increase due to the action of the ammonia-salts.

Reference has already been made to the probable or possible cause of the much greater produce of barley than of wheat by the mineral manure alone (p. 93). On this point it should be borne in mind that, for the wheat the mineral manures, as well as the ammonia-salts, are applied in the autumn, whereas for the barley both are applied in the spring. It is a question, therefore, whether there be not a much greater dilution and distribution of the autumn-sown mineral manures by the winter rains; a locking-up of some of their constituents in difficultly soluble combinations within the soil; hence a less active root-development in the upper and more highly nitrogenous layers of the soil when growth commences in the spring; and hence, also, less luxuriance in the case of the wheat; but, on the other hand, a more rapid exhaustion of the previously accumulated nitrogen within the soil by the barley. If this be so, the higher produce of barley than of wheat by mineral manures alone is, in a sense, accidental, and may prove not to be permanent. In that case, the comparison of the actual *produce* will more fairly illustrate the difference of effect of the mineral manure and a given amount of ammonia-salts applied to wheat and to barley, than will that of the mere *increase* over the produce by the mineral manure alone; and the less amount of increase of barley than of wheat so calculated in these last experiments, will prove no exception to the conclusion arrived at from the results of the other experiments, namely, that a given amount of ammonia-salts applied in the spring for barley is more productive than an equal amount applied in the autumn for wheat.

Briefly enumerated, the very important results, obtained by the use of nitrogenous and mineral manures together, are—that much more than the average barley crop of the country has been obtained for 20 years in succession on the same land, by the annual application, in the spring, of 200 lbs. of ammonia-salts, and 3½ cwts. superphosphate of lime; that the addition of salts of potass, soda, and magnesia, gave no further increase; and that the application, for the same period, of the same amount of ammonia-salts (with mineral manure) in the autumn, for wheat, gave nearly 37 per cent. less corn, nearly 14 per cent. less straw, and about 24 per cent. less total produce. The causes of the remarkable differences of result with wheat and with barley will be considered in Section IV.

Average annual produce and increase by Rape-cake.

Rape-cake is estimated to contain, on the average, about 4·75 per cent. of nitrogen. It also contains a large amount of carbonaceous organic substance, and about 8 per cent. of mineral matter. It has been applied on 4 plots each year; on one alone, on one with superphosphate, on one with the "mixed alkali-salts," and on one with both superphosphate and the mixed alkali-salts. For the first 6 years 2000 lbs. = 95 lbs. nitrogen, were applied per acre per annum; but during the next 14 years only 1000 lbs. = 47·5 lbs. nitrogen. Table XXXVIII. (p. 112) shows the produce over the first 6 years with the larger amount, over the last 14 years with the smaller amount, and both produce and increase over the whole 20 years.

It is first to be observed that where the rape-cake is used without superphosphate, Plots 1 and 3, there is much less deficiency of produce, both corn and straw, compared with Plots 2 and 4 with superphosphate, than in the experiments with ammonia-salts without, compared with those with, superphosphate. The fact is that the rape-cake itself supplies some phosphates; so that superphosphate has less effect when added to it than to ammonia-salts. The general result is, that the rape-cake alone, and the rape-cake and mixed alkali-salts, yield considerably more of both corn and straw than ammonia-salts alone, or ammonia-salts and mixed alkali-salts; but, where used with superphosphate, there is more produce of both corn and straw from a less amount of nitrogen supplied as ammonia-salts, or nitrate of soda, than from a larger quantity in rape-cake.

Thus, over the first 6 years, rape-cake in amount supplying 95 lbs. of nitrogen per acre per annum was applied, and over the same period ammonia-salts = 82 lbs. of nitrogen. But where each was used with superphosphate, whether without or with the addition of the mixed alkali-salts, there was more produce of both corn and straw by the ammonia-salts than by the rape-cake. In fact, there was not much less barley-grain, though a greater deficiency of straw, with superphosphate and ammonia-salts = only 41 lbs. of nitrogen, than with superphosphate and rape-cake = 95 lbs. of nitrogen.

Over the next 14 years the application of rape-cake was reduced to 1000 lbs. per acre per annum = 47·5 lbs. nitrogen; and where ammonia-salts = 82 lbs. nitrogen had previously been applied, the quantity was also reduced to one-half = 41 lbs. nitrogen. The result in each case was that, with superphosphate and the reduced amount of nitrogenous manure, there was an average annual produce of about as much corn, though less

TABLE XXXVIII.—Average Annual Produce and Increase by Rape-cake.

Plots.	MANURES PER ACRE, PER ANNUM.	AVERAGE ANNUAL PRODUCE, &c.				AVERAGE ANNUAL INCREASE, 20 YEARS, 1852–1871.	
	2000 lbs. Rape-cake, 6 yrs., 1852-'57. 1000 lbs. Rape-cake, 14 yrs., 1858-'71. Without Mineral Manure, and with Mineral Manures as under.	First Period, 6 Years, **1852–'57.**	Second Period, 14 Years, **1858–'71.**	Total Period, 20 Years, **1852–'71.**	Second Period, over (or under −) First.	Over (or under −) Mean Unmanured.	Over (or under − corre- sponding Mineral Manure
	Dressed Corn, per Acre—Bushels.						
					Per Cent.		
1 C	Without Mineral Manure..	48¼	44	45⅜	− 8·8	24⅜	
2 C	Superphosphate of Lime ..	47¾	46½	46⅞	− 2·6	25⅞	21¼
3 C	Mixed Alkali-salts	44½	43¼	43¾	− 2·8	22¾	21¼
4 C	Superphosphate and Mixed Alkali-salts	48	47⅛	47½	− 1·8	26½	20
	Total Corn, per Acre—lbs.						
1 C	Without Mineral Manure..	2664	2527	2568	− 5·1	1380	
2 C	Superphosphate of Lime ..	2673	2660	2664	− 0·5	1476	1225
3 C	Mixed Alkali-salts	2505	2489	2494	− 0·6	1306	1226
4 C	Superphosphate and Mixed Alkali-salts	2662	2713	2698	1·9	1510	1148
	Straw (and Chaff), per Acre—Cwts.						
1 C	Without Mineral Manure..	31⅝	24¾	26⅞	−21·9	14¾	
2 C	Superphosphate of Lime ..	32⅜	26⅝	28⅜	−17·8	16¼	15
3 C	Mixed Alkali-salts	30¼	25¾	27⅛	−15·0	15	14⅞
4 C	Superphosphate and Mixed Alkali-salts	32½	28¼	29½	−13·1	17⅜	15⅛
	Total Produce (Corn Straw, and Chaff), per Acre—lbs.						
1 C	Without Mineral Manure..	6212	5296	5571	−14·7	3029	
2 C	Superphosphate of Lime ..	6305	5646	5844	−10·5	3302	291[illegible]
3 C	Mixed Alkali-salts	5895	5369	5527	− 8·9	2985	288[illegible]
4 C	Superphosphate and Mixed Alkali-salts	6300	5875	6002	− 6·7	3460	284[illegible]
	Weight per Bushel of Dressed Corn—lbs.						
1 C	Without Mineral Manure..	51·0	55·0	53·8	7·8	1·4	
2 C	Superphosphate of Lime ..	51·2	55·0	53·9	7·4	1·5	0·[illegible]
3 C	Mixed Alkali-salts	51·1	54·9	53·7	7·4	1·3	0·[illegible]
4 C	Superphosphate and Mixed Alkali-salts	50·7	54·9	53·6	8·3	1·2	2·[illegible]
	Corn to 100 Straw.						
1 C	Without Mineral Manure..	75·4	92·4	87·3	22·5	−0·8	
2 C	Superphosphate of Lime ..	74·1	90·5	85·6	22·1	−2·5	−11[illegible]
3 C	Mixed Alkali-salts	74·2	87·5	83·5	17·9	−4·6	− 8[illegible]
4 C	Superphosphate and Mixed Alkali-salts	73·3	87·2	83·0	19·0	−5·1	−13[illegible]

straw, than with the previous too heavy dressings. There was, moreover, not only more corn and more straw by the superphosphate and the reduced amount of ammonia-salts, but also more where ammonia-salts = only 41 lbs. of nitrogen had been used from the commencement, than by the superphosphate and the rape-cake.

The nitrogen of the nitrogenous organic matter of the rape-cake would doubtless be much less rapidly available than that supplied in ammonia-salts; and analysis of the soil has shown that the rape-cake has left a considerable residue of nitrogen near the surface; nor can there be any doubt that, since the excessive dressings of both ammonia-salts and rape-cake have been stopped, there has annually been some effect due to the unexhausted residue of nitrogen previously applied.

The general result is, that about 9 cwts. of rape-cake per acre per annum have given a produce exceeding the average crop of the country, but not quite a maximum yield for the soil and seasons in question. The mineral constituents of the rape-cake doubtless serve to render effective the nitrogen associated with them; though there can be little doubt that the increase yielded is mainly dependent on the amount of nitrogen rendered available by the decomposition of the nitrogenous organic matter of the rape-cake. But since the effect is less for a given quantity of nitrogen supplied, than when ammonia-salts or nitrate of soda is used, it is impossible to decide absolutely whether, or in what degree, the carbonaceous organic matter has been of service. It would yield by decomposition carbonic acid and other products. The increased supply of carbonic acid in the soil would, it must be concluded, not only serve as a source of carbon, but aid the solution and distribution of other plant-food, and so far further growth. But that any such supply is essential for the successful growth of either wheat or barley is clearly disproved by the fact that maximum crops of both have been grown for 20 years or more by means of mineral manures and ammonia-salts, without any return to the soil of carbonaceous organic matter. The carbonaceous organic matter of farmyard manure is obviously equally unessential, so far as the successful growth of the cereals is concerned.

Summary of the Results obtained on the Growth of Barley for 20 Years in succession on the same land, without Manure, and by different descriptions of Manure.

1. Without manure, the average annual produce of barley over 20 years was about 21 bushels of dressed corn, and 12 cwts. of straw. The quality, indicated by the weight per bushel of grain,

was higher over the second than over the first 10 years; but the quantity, of both corn and straw, was between 23 and 24 per cent. less over the second 10 years.

2. Compared with wheat grown for many years in succession without manure, barley gave an average of more corn, less straw, and nearly the same weight of gross produce (corn and straw together); but the barley fell off more in produce of grain, and about equally in straw, over the later years.

3. Farmyard manure applied every year for 20 years, gave an average annual produce of more than 48 bushels of barley-grain, and 28 cwts. of straw. The weight per bushel, quantity of grain, and quantity of straw, were all considerably higher over the second than over the first 10 years. The manure probably supplied from three to four times as much nitrogen as any of the artificial manures, and much more of carbonaceous organic matter, and of every other constituent of the crop, than was contained in the produce. It would leave a large residue of nitrogenous, carbonaceous, and other matters in the soil, which seem to be very slowly available for future crops; but the large accumulation of organic matter increases the porosity of the soil, and its capacity for the retention of moisture; and the crops are thereby rendered both less susceptible to injury from excess of rain, and more independent of drought.

4. As without manure, so with farmyard manure, barley, compared with wheat, yielded, over a series of years, more corn, less straw, but nearly the same quantity of total produce (corn and straw together). This is remarkable, when it is considered that the wheat is autumn-sown and autumn-manured, and the barley spring-sown and spring-manured.

5. Mineral manures alone gave very poor crops, and the quantity of both corn and straw fell off considerably during the later years; but superphosphate of lime alone gave more than salts of potass, soda and magnesia, and not much less than the mixture of all. It may be concluded that the soil was not relatively deficient in any of the mineral constituents which the manures supplied; and, from the falling off in the produce both without manure and with purely mineral manures, it is probable that the growth of the crop under such conditions is gradually exhausting the available nitrogen accumulated within the soil from previous cultivation, manuring, and cropping.

6. Over the same period of 20 years, a mixed mineral manure, containing salts of potass, soda and magnesia, and superphosphate of lime, gave, of barley, much more grain, rather less straw, but considerably more total produce, than of wheat. It is probable that, with the autumn-manuring for the wheat, the various constituents are distributed by the rains, or enter into

less soluble combinations, or both, during the winter; that hence there is less active root-development in the upper and more highly nitrogenous layers of the soil in the spring, and that hence the barley is more rapidly exhausting the accumulated nitrogen of the surface-soil than the wheat.

7. By nitrogenous manures alone (ammonia-salts or nitrate of soda) much more barley was obtained than by mineral manures alone; the produce declined much less in the later years; and, for 20 years in succession, even fair, though not large, crops were obtained. This result is a striking illustration of the mineral resources of such a soil; and it shows that when in what may, in an agricultural sense, be called a corn-exhausted condition, it was deficient in available nitrogen relatively to available mineral constituents.

8. By ammonia-salts and superphosphate of lime together, an average produce of more than 47 bushels of dressed corn, and more than 28½ cwts. of straw, or considerably more than the average barley crop of the country, was obtained over 20 years in succession; and the produce of corn increased, and that of straw in a less degree diminished, giving a higher total produce, during the later than the earlier years. Notwithstanding the great demand made upon the supplies of potass within the soil, by the growth of the crop for so many years by ammonia-salts and superphosphate without potass, the addition of salts of potass, soda and magnesia, gave no further increase of corn, and very little of straw and total produce. The potass-yielding capabilities of such a soil, and the beneficial effects of the use of superphosphate, with nitrogenous manures, for spring-sown corn crops, are here strikingly illustrated.

9. When the same mixed mineral manure, and 200 lbs. of ammonia-salts, were applied per acre per annum for 20 years, in the autumn for wheat, and in the spring for barley, the barley gave more than one-half more corn, nearly one-sixth more straw, and nearly one-third more total produce, than the wheat. When the same mineral manure was used with a larger quantity of ammonia-salts, the result was still in favour of the barley, but in a less degree than with the smaller amount.

10. After applying 400 lbs. of ammonia-salts per acre per annum to barley for 6 years, and then reducing the amount to 200 lbs., the plots so treated gave, for 10 years in succession, more produce than those which had only received 200 lbs. annually from the commencement. It thus appears that the excessive supply of 400 lbs. had left a residue of nitrogen within the soil which was available for succeeding crops.

11. The experiments on barley with nitrate of soda and ammonia-salts respectively, are not exactly comparable with one

another; but, so far as can be judged, a given amount of nitrogen as nitrate of soda has yielded more produce than the same amount as ammonia-salts, and especially so in dry seasons. This is probably due to the greater solubility of the nitrate, or its products of decomposition, to their action on the subsoil, disintegrating it, and rendering it more porous; thus affording more surface for the absorption and retention of moisture and manure, and greater permeability to the roots, rendering the plants less dependent on the fall of rain during growth.

12. By the annual application of rape-cake, whether without or with the addition of mineral manures, more barley than the average crop of the country has been obtained; but, in proportion to the nitrogen it contained, less than by ammonia-salts or nitrate of soda. The mineral constituents of the rape-cake no doubt aid in rendering effective the nitrogen associated with them, though its effects are doubtless mainly dependent on the amount of nitrogen rendered available by the decomposition of its nitrogenous organic matter; but the nitrogen of such matter is much less rapidly available than that of ammonia-salts or nitrates.

13. Over 20 years or more, in succession, ammonia-salts, or nitrate of soda, with mineral manure (without silica), have yielded considerably more of both wheat and barley than the average crops of the country, and more also than either farmyard manure or rape-cake. It is obvious, therefore, that the return to the soil of carbonaceous organic matter as manure is unessential, so far as the successful growth of either of these crops is concerned.

Section III.—Amount of Ammonia in Manure (or its equivalent of Nitrogen in other forms) required to yield a given increase of Grain (and its proportion of Straw).

Comparison of the produce obtained by the different manures has shown—that carbonaceous organic matter, supplied so largely in farmyard manure and rape-cake, is at any rate not essential as manure for either wheat or barley; that mineral manures alone will not yield fair crops of either; that nitrogenous manures give much more produce than mineral manures alone; and that the mixture of nitrogenous and mineral manures will give full crops for many years in succession. In other words—the supply by manure of matter yielding by decomposition carbonic acid, and other carbon compounds, within the soil, has little or no effect; mineral manures alone will not enable the growing plant to obtain sufficient nitrogen from the soil or the atmosphere;

TABLE XXXIX.—Quantity [...] Rape-cake, or Farmyard Man[...] [...]ied per acre, to the available s[...]

PLOTS.	MINERAL [...]	HARVEST[...]				
		1857.	1858.	1859.	1860.	18[...]
		[...]—200 lbs. Ammonia-salts per acr[...]				
		lbs.	lbs.	lbs.	lbs.	lb[...]
1 A.	Without Mineral M[...]	3·82	4·61	18·05	3·41	3·[...]
2 A.	Superphosphate of[...]	2·00	2·12	3·04	1·75	1·[...]
3 A.	Mixed Alkali-salts[...]	4·63	4·73	24·75	3·75	3·[...]
4 A.	Superphosphate an[...]	2·54	2·33	3·17	1·91	1·[...]
5 A.	Superphosphate an[...]	2·00	1·98	2·88	1·63	2·[...]
		3·00	3·15	10·38	2·49	2·[...]
		[...] 6 years, 1852–'57; 200 lbs. next [...]				
1 AA	Without Mineral [...]	4·09	2·62	5·63	4·05	2[...]
		2·83	1·77	2·71	1·79	1[...]

nyard Ma
available s
HARVES
1860. 18
alts per acr
lbs. ll
3·41 3·
1·75 1·
3·75 3·
1·91 1·
1·63 2·
2·49 2·
lbs. next
4·05 2
1·79 1

ıitrogen in an available form was liberally provided, the ıl constituents of the soil were insufficient for its full effect; ıen so supplied, the mineral manures, which alone had little greatly increased the efficacy of the supplied nitrogen. ɘ general result is, that whilst it is essential that there be a l provision of mineral constituents, the amount of produce nore dependent on the supply of *available nitrogen within il* than of any other constituent. The practical questions usly arise—How much ammonia, or of its equivalent of gen in some other form, will, on the average, be required to a given amount of increase of barley-grain, and its average ɔrtion of straw? and how much will the quantity vary, ding to the amount applied per acre, to the supply of ral constituents, and to the characters of the seasons?

ne folding Table XXXIX. (facing this page) shows the ant of ammonia—or of nitrogen in nitrate of soda, or rape- , or farmyard manure, reckoned as ammonia—required to l 1 bushel (52 lbs.) of increase of barley-grain, and its pro- ion of straw, under a great variety of conditions of manuring, in each of the 20 seasons. In each case the increase is calcu- l over the produce on the corresponding plot without nitro- ous manure; that is, 1 A, 1 AA, 1 AAS, 1 C, over 1 O; , &c., over 2 O; and so on; 1 N, and 2 N (with nitrate of), and 7 (with farmyard manure), are taken over the mean nanured produce (1 O and 6-1). The average result for erent periods, or series of years, is also given. Where there been no change of manure, the averages are, as a rule, calcu- d for the first half, the second half, and the total period; and re there has been any change, for the periods so indicated; , for the sake of comparison, for corresponding periods in er cases.

The five plots receiving 200 lbs. of ammonia-salts per acre annum for 20 years are classed in the Table as Series I. these, Plot 1 A has had the ammonia-salts without any neral manure; 2 A with superphosphate; 3 A with sul- ates of potass, soda, and magnesia: 4 A with superphosphate d sulphates of potass, soda, and magnesia; and 5 A with perphosphate and sulphate of potass. Taking the average for e 20 years in each case, the quantity of ammonia required to roduce 1 bushel increase of barley, and its proportion of straw, , on the three plots with superphosphate 2·13, 2·41, and 2·10 lbs.; n the plot with salts of potass, soda, and magnesia, without uperphosphate, 3·59 lbs.; and on the one without any mineral nanure at all 3·68 lbs.

Thus, taking the mean of the three experiments with super- phosphate, the amount of ammonia required is rather under 2¼ lbs.;

but with the mixed alkali-salts without superphosphate, and without any mineral manure at all, it is between 3½ and 3¾ lbs. That is to say, a given amount of ammonia-salts was more than one-and-a-half-time as effective when there was a liberal provision of mineral constituents, but especially of phosphates, within the reach of the roots, than when there was not.

Assuming that, with otherwise favourable soil-conditions, and with an application of not more than 50 lbs. of ammonia per acre, an increase of 1 bushel of barley (52 lbs.), and its straw, may, on the average of seasons, be obtained for every 2 to 2¼ lbs. of ammonia applied, still, it is seen that the amount may vary very greatly according to the characters of the seasons. Thus, on Plot 2 A, with superphosphate, only about 1½ lb. was required in the favourable seasons of 1863 and 1869, but in the bad seasons of 1853 and 1856, 5·36 and 4·48 lbs. respectively, were required.

These great differences according to season occurred, it should be remembered, when only a moderate amount of ammonia-salts was used, and when it was employed under favourable conditions as to mineral manures. But even with the same moderate application, but at the same time less favourable soil-conditions, that is without superphosphate, or without any mineral manure, the differences in the amount required to yield a given increase of produce are very much greater. Thus, when the same quantity of ammonia-salts is used without any mineral manure (Plot 1 A), there is a variation in the amount of ammonia required to yield 1 bushel of increase from 18·05 lbs. in 1859, to 2·25 lbs. in 1871; and when with salts of potass, soda, and magnesia, but without superphosphate (Plot 3 A), from 24·75 lbs. in 1859, to 2·18 lbs. in 1863. In fact, in 1859, there was scarcely any increase at all by ammonia-salts when not accompanied by phosphates; and reference to the characters of the season, and of the growth (pp. 30-32), will show that there was probably defective root-development; a condition under which any deficiency of phosphates within a limited range of soil would very unfavourably affect the characters of growth.

Lastly in regard to Series I:—Under each of the five conditions as to mineral manuring, the amount of ammonia required to produce a given increase of grain was very much less over the second than the first 10 years. It has already been shown that the last 10 seasons were the more favourable for the production of corn, and more especially so where superphosphate was used. But, as there was a greater falling off over the later years where the mineral manures were used alone, the further amount of produce obtained where the mineral manures and ammonia-salts were used together, which is reckoned as increase due to ammonia, was proportionally higher over the last ten years, than was the increase in the actual produce of corn per acre. Further, the actual produce of straw per acre was uniformly, and that of the total produce (corn and straw), taking the average of the plots, rather lower, over the last ten years. That the total produce was lower rather than higher over the later years, seems to afford evidence that, with this smaller dressing of ammonia-salts, there was little or no effect in succeeding, from accumulation in preceding years.

When, as in Series II., double the quantity, or 400 lbs. ammonia-salts, was applied per acre per annum for the first six years, the average amount of ammonia required to yield 1 bushel of increase was, according to the same mode of calculation, without mineral manure, 4·81 lbs.; with superphosphate, 5·06 lbs.; with mixed alkali-salts 6·38 lbs.; and with superphosphate and mixed alkali-salts, 5·86 lbs. Thus, the amount required appears to be less without, than with either of the mineral manures, less with superphosphate than with superphosphate and mixed alkali-salts, and less with the latter than with mixed alkali-salts without superphosphate. The apparently more favourable result without than with mineral manure, is explained by the fact, that the increase by ammonia-salts is, in each case, calculated over the produce by the corresponding unmanured or mineral-manured produce, as the case may be; and as the produce by mineral manures, especially if containing phosphates, was so much higher than that without manure, there is so much more to deduct from the produce with ammonia-salts in addition; and hence, though the produce by the ammonia-salts with mineral manure is much higher, the increase so reckoned as due to the ammonia only is less.

During the next ten years, the quantity of ammonia-salts was reduced from 400 lbs. to 200 lbs.; and during the last four years the ammonia-salts were replaced by 275 lbs. of nitrate of soda, estimated to contain the same amount of nitrogen as 200 lbs. ammonia-salts, namely 41 lbs. = 50 lbs. ammonia. Over both of these periods the result is much more favourable with each of the four conditions as to mineral manure than during the first six years, and also relatively much more so where the superphosphate was employed. This depends in part on the fact that, whilst the produce without manure or by the mineral manures alone, which is the standard over which the increase by ammonia is calculated, declined perceptibly from year to year, that where ammonia was used either did not decline at all, or did so much less rapidly; and hence the increase calculated as due to the ammonia (or nitrogen reckoned as ammonia) is higher.

In reference to these results it should further be observed, that since there is evidence that the excessive supply of ammonia-salts during the first six years left a residue of nitrogen which was effective for ten, if not more, years afterwards, not only do the figures for the first six years understate the total or final effect of the ammonia applied during that period, but those for the subsequent years overstate the result for those years. The average columns of the Table give, however, not the mere arithmetical means of the results for the individual years, but the direct averages for the periods; and the result over the twenty years is, that, instead of only 2·13 lbs. of ammonia required when superphosphate and only 200 lbs. of ammonia-salts were used, there were 2·49 lbs. required when, for the first 6 of the 20 years, 400 lbs., for the next 10 years 200 lbs., ammonia-salts, and for the last 4 years 275 lbs. nitrate of soda, were applied. There is also a considerably less favourable result without than with the superphosphate. Lastly, as in the experiments with the smaller quantity of ammonia-salts every year, the variation of result according to season is very considerable; but, owing to the excess of ammonia applied in the early years, and to the effects of the accumulation afterwards, the exact figures for the individual years cannot be taken in illustration of the point.

During the last eight years of the twenty, one-half of the plots of Series II. received, besides the same manures as the other half, 400 lbs. of silicate of soda, per acre, per annum. The four portions so treated are respectively designated 1 AAS, 2 AAS, &c.; and the results are recorded in the Table under the heading of Series III. Almost every year it was quite obvious to the eye that there was a marked effect from the silicate on Plots 1 and 3, that is where no superphosphate was used; but comparatively little, if any, on Plots 2 and 4 with superphosphate. So striking was this result, that the silicate was examined in the laboratory to ascertain whether it contained any phosphate. It was found not to contain any; nor did it contain nitrate or nitrogen in any other form. Perhaps the most probable supposition is, that by the action of the alkaline silicate on the soil, otherwise locked up phosphoric acid was rendered available for the plants. It is possible, however, that, when the superphosphate was used, a secondary result of its action within the soil was the liberation of silicates, which, without it, were not available in sufficient quantity; and hence the little effect of the direct supply of silicates where the superphosphate was used, and the marked effect where it was not employed. Or, is it that when the acid-phosphate and alkaline silicate are mixed together, they are rendered comparatively insoluble and inactive? The result may perhaps be due in part to more than one of these actions.

Whatever may be the explanation of the fact, the Table shows that there was, in almost every year of the eight, comparatively little difference in the amount of ammonia required to yield a bushel of increase of barley on Plots 2 and 4 of Series II. with superphosphate but without the silicate, and on Plots 2 and 4 of Series III. with superphosphate and with silicate. On the other hand, on Plots 1 and 3 of Series III., without superphosphate, but with silicate, the amount of ammonia required for a given effect was much less than on the corresponding plots of Series II. without the silicate. There was also a greater increase of straw by the use of the silicates where superphosphate was not, than where it was employed.

The next experiments to consider are those with nitrate of soda alone (Series IV.). 1 N received, for nineteen years in succession, 275 lbs. nitrate of soda, containing nitrogen = 50 lbs. ammonia; and 2 N received, for the first five of the nineteen years, double the amount, or 550 lbs. = 100 lbs. ammonia, and afterwards, for fourteen years, only 275 lbs., as Plot 1 N. But as, in the first year of the twenty, both plots received superphosphate of lime and sulphate of potass in considerable amount, which doubtless increased the effects of the nitrogen subsequently supplied for many years, if not for the whole period, the results of 1 N are not strictly comparable with those of 1 A receiving annually the same amount of nitrogen as ammonia-salts, nor are those of 2 N comparable with those of 1 AA. As the figures stand, however, the average of twenty years with ammonia-salts, and of nineteen with nitrate of soda = 50 lbs. of ammonia, shows with the ammonia-salts 3·68 ammonia, and with the nitrate, nitrogen = only 2·74 lbs., required to yield 1 bushel increase of grain and its straw; and with the double amount during the first few years, the ammonia-salts show 3·53, and the nitrate only 2·81 lbs. required. It has already been explained (pp. 94-6) that enough phosphoric acid and potass were applied on the nitrate plots in the first year, to supply as much of these constituents as would be contained in the excess of produce by the nitrate over that by the ammonia-salts throughout the subsequent period; so that, obviously, only part of the better result of the nitrate can be supposed to be due to the condition of combination of its nitrogen.

The result is, at any rate, remarkable, that after mineral manures once applied, nitrate of soda alone should, for nineteen years in succession, yield a result in proportion to its nitrogen, comparatively so little inferior to ammonia-salts used every year in conjunction with superphosphate, or with superphosphate and salts of potass, soda and magnesia.

The next experiments are those of Series V., in which rape-cake was used without, and with mineral manures. During the first

6 years 2000 lbs., and during the last 14 years 1000 lbs. per acre per annum were applied. The rape-cake is calculated to contain 4·75 per cent. of nitrogen. This estimate is not founded on direct analysis of the lots actually employed, but is deduced from our own and published results on various samples in the market. Adopting it, the 2000 lbs. would contain 95 lbs. nitrogen = 115·4 lbs. ammonia, and the 1000 lbs., 47·5 lbs. nitrogen = 57·7 lbs. ammonia.

As the manure leaves a considerable residue for future crops, and would especially do so during the first 6 years, the calculation of the whole of the nitrogen supplied, against the increase obtained during that period, does not show the total or final effect of the nitrogen so supplied; whilst, during the succeeding 14 years, the figures will represent the result too favourably, in so far as a portion of the increase will doubtless be due to accumulation from the previous applications; and this would probably be more considerable, and more effective, than in the case of the double supply of ammonia-salts (Series II.). Accordingly, the figures show much more nitrogen applied for the production of a bushel of increase during the first 6, than during the last 14 years.

As already explained, the increase is, as in the experiments with ammonia-salts, calculated over the produce on the corresponding plots without nitrogenous manure. This plan is, upon the whole, less open to objection than taking the increase in each case over the unmanured produce; but a consideration of the results will show that it is by no means without objection.

The general result is, that the experiments with rape-cake show less difference and less beneficial effect due to the mineral manures also used, than those with ammonia-salts. Thus, comparing the results with rape-cake over the last 14, or the 20 years, with those of Series II., with ammonia-salts over the same periods (both manures being applied in double quantity during the first 6 years), considerably less nitrogen, reckoned as ammonia, is calculated to have been required to yield a given increase with ammonia-salts than with rape-cake when superphosphate was also used, but considerably less with rape-cake than with ammonia-salts, when each was used without superphosphate.

The fact is that rape-cake itself contains phosphates and other mineral constituents, which serve to render the nitrogen associated with them the more effective. It is obvious, therefore, that calculating the increase by the rape-cake alone over the produce without manure, and that by rape-cake and mineral manure over the produce by the corresponding mineral manure alone, gives a relatively too favourable result for the rape-cake where it is used alone, and too unfavourable where it is used with the mineral manures. For, when used alone, the increase so reckoned as due to the nitrogen only, includes that due to the associated mineral constituents of the rape-cake; but when used with mineral manures, the increase due to the mineral constituents directly applied is deducted. On this point it may be mentioned that, if the increase were, in all four experiments with rape-cake, calculated over the unmanured produce, the result would appear, both actually and relatively, more favourable where mineral manures were also used, than the figures in the Table show.

The comparison between the ammonia-salts and the rape-cake is, of course, so far as the nitrogen is concerned, the fairest where the mineral conditions were the most equally favourable with both manures; that is where superphosphate was used. The less favourable result with the rape-cake under these conditions is, doubtless, due to its nitrogen becoming less rapidly available than that of the ammonia-salts. Still, upon the whole, it would appear that not very much more nitrogen is required in rape-cake than in ammonia-salts to yield a given amount of immediate increase; and an advantage of the rape-cake is, not only that it itself supplies mineral constituents, so that with it less superphosphate, if any, will be required, but that its nitrogen will probably be less liable to loss by drainage than that of ammonia-salts or nitrate of soda. On the other hand, a given amount of nitrogen costs more in rape-cake than in either sulphate of ammonia or nitrate of soda.

The last illustrations relate to the results obtained by farmyard manure. As in the case of the rape-cake, the quantity of nitrogen applied can only be approximately estimated. In the calculations it has been assumed that the dung contained 0·64 per cent. of nitrogen = 0·77 per cent. of ammonia. This result is arrived at by calculations founded on the average composition of the matters supposed to enter into the dung. It agrees almost precisely with determinations recently made in dung from the farmyard at Rothamsted; but it is rather less than has been found here in good box dung. It is almost exactly the mean of the results of Boussingault and Voelcker for fresh dung. But it is considerably higher than results recently published by Professor Anderson.

As has been stated, the produce on the farmyard-manure plot has increased considerably in recent years; and accordingly the Table shows much less nitrogen = ammonia required to yield a bushel of increase in the later than in the earlier years. There has indeed been a great accumulation, the effects of which have been only very gradually developed. Taking the average of the 20 years, however, it has required 8 lbs. of ammonia, or its equivalent of nitrogen, in dung, to yield one bushel increase of barley, and its straw; in other words, nearly four times as much as when a mixture of ammonia-salts and superphosphate was employed. This is a striking illustration of the slowness of the return from nitrogen supplied in farmyard manure compared with that in ammonia-salts or nitrate of soda. It is obviously an important question whether less or more of the at first unrecovered amount is lost by drainage, or otherwise, in the one case than the other? or whether the residue from the one description of manure is more or less effective than that from the other? These points have already been referred to in some of their aspects, and will be further considered in the next Section (IV.); but data are still wanting for their full and satisfactory settlement.

From a review of the whole of the data brought forward relating to the point, the practical conclusion may be drawn, that when an increase of barley is obtained by means of artificial manures, such as sulphate of ammonia, or nitrate of soda, or Peruvian guano, an increase of 1 bushel of grain (52 lbs.), and its proportion of straw (say 63 lbs.), may, taking the average of seasons, be calculated upon for every 2 to 2¼ lbs. of ammonia, or its equivalent of nitrogen (1·65 to 1·86 lb.), supplied in the manure—provided the amount applied be not excessive, and provided there be no deficiency of mineral constituents within the soil.

These conditions will be fulfilled when barley, grown after dunged roots carted off, or after another corn crop, is manured by from 1½ to 2 cwts. of sulphate of ammonia, or 1¾ to 2¼ cwts. of nitrate of soda, with 2 to 3 cwts. of superphosphate, per acre; or, from 3 to 4 cwts. of Peruvian guano, containing 12 per cent. of ammonia, without superphosphate.

When, however, rape-cake is used, rather more nitrogen in that form will be required to yield a given increase of the crop for which it is applied; but when the increase is obtained by sheep-folding, or farmyard manure, very much less will be obtained in the first crop, in proportion to the nitrogen contained in the manure.

In our Report on the growth of wheat for twenty years in succession on the same land, it was shown for that crop, as now it is for barley, that the quantity of increase obtained for a given amount of ammonia, or its equivalent of nitrogen, in manure, varied exceedingly according to the amount applied, to the provision of mineral constituents within the soil, and to the seasons. It was, however, stated, as a general practical conclusion, that, under the conditions the most camparable with those of ordinary practice, approximately 5 lbs. of ammonia, or its equivalent of nitrogen, were on the average required to yield 1 bushel increase of wheat, and its proportion of straw. Now, 1 bushel of wheat may be reckoned to weigh 61 lbs., and its average proportion of straw 105 lbs. Thus, whilst from 2 to $2\frac{1}{4}$ lbs. of ammonia in manure will yield 52 lbs. barley-grain, and 63 lbs. straw = 115 lbs. total produce, it required 5 lbs. to yield 61 lbs. of wheat-grain, and 105 lbs. straw = 166 lbs. total produce.

It is clear that it required much more nitrogen in manure to yield a given amount of increase of produce when applied in the autumn for wheat, than when in the spring for barley.

The questions remain—what proportion of the supplied nitrogen is recovered in the immediate increase of crop?—what becomes of the unrecovered amount, if any?—does it, wholly or in part, remain in the soil?—if so, what will be its effect on succeeding crops?—or, lastly, is there any material loss, by drainage, or otherwise? These points will next be considered.

Section IV.—On the Effects of the unexhausted Residue from previous Manuring upon succeeding Crops, Loss of Constituents by Drainage, and some allied Points.

In the foregoing pages incidental reference has frequently been made to the effects of the residue from previous manuring upon succeeding crops; but the subject is, in various aspects, of such great importance, that it has been reserved for separate consideration in this place.

For example, it is of very great practical interest to have some exact data, showing—what proportion of the nitrogen, supplied in manure, will probably be recovered in the increase of the crop for which it is applied; whether, or in what degree, the at first unrecovered amount will, on the one hand be retained by the soil, or on the other, be drained away and lost? whether, if retained, it will remain, wholly, or in part, in such a state of combination, and distribution, within the soil, as to be available for succeeding crops? and so on.

Very similar questions obviously arise in regard to the mineral constituents of manures and crops; and so far at least as some of those constituents are concerned, it is very important to be able to refer to direct experimental evidence, bearing on the subject.

But, independently of facts and conclusions of great general interest and importance, when the same manure is applied, and the same crop grown, year after year on the same land, it is essential to a proper interpretation of the average results obtained over a series of years, not only to consider the characters of the seasons, but also whether any particular description of manure, so applied, induces exhaustion of certain constituents, resulting in diminished, or accumulation tending to increased, productiveness from year to year.

In our Report on the growth of wheat for 20 years in succession on the same land, the question of the effects of the unexhausted residue from previous manuring upon succeeding crops, was considered so far as evidence was then at command, and it is proposed to give some further illustrations relating to that crop. The experiments on barley afford but few illustrations of the point; but it will be instructive to call attention to such as are available, to consider how far their indications agree with, and how far they differ from, those relating to wheat, and to endeavour not only to explain the general facts observed, but to ascertain the reason of any differences of result with the two crops.

The effects of the unexhausted residue of nitrogen, supplied as ammonia-salts, or nitrate of soda, will first be considered.

Table XL. relates to experiments on barley with ammonia-

TABLE XL.—Effects of the Unexhausted Residue of Nitrogen applied to Barley as Ammonia-salts.

YEARS.	PRODUCE PER ACRE.								
	TOTAL CORN IN BUSHELS OF 52 lbs.			STRAW (and Chaff).			TOTAL PRODUCE (Corn and Straw).		
	Mixed Mineral Manure every Year, and—			Mixed Mineral Manure every Year, and—			Mixed Mineral Manure every Year, and—		
	Plot 4 A. 200 lbs. Ammonia-salts every Year.	Plot 4 AA. 400 lbs. Ammonia-salts, 6 Years, 1852–'57; 200 lbs., 10 Years, 1858–'67.	4 AA over (or under –) 4 A.	Plot 4 A. 200 lbs. Ammonia-salts every Year.	Plot 4 AA. 400 lbs. Ammonia-salts, 6 Years, 1852–'57; 200 lbs., 10 Years, 1858–'67.	4 AA, over (or under –) 4 A.	Plot 4 A. 200 lbs. Ammonia-salts every Year.	Plot 4 AA. 400 lbs. Ammonia-salts, 6 Years, 1852–'57; 200 lbs., 10 Years, 1858–'67.	4 AA, over (or under –) 4 A.
	Bushels.	Bushels.	Bushels.	Cwts.	Cwts.	Cwts.	lbs.	lbs.	lbs.
Average, 6 years, 1852–'57	49⅞	53⅞	4	29¼	36⅜	7⅛	5,863	6,874	1,011
1858	55⅝	60⅝	5	29⅜	35¾	6⅜	6,192	7,160	968
1859	38¾	40⅛	1¾	27¼	30⅝	3⅜	5,067	5,517	450
1860	45⅝	48⅛	2½	26⅝	29	2⅜	5,355	5,746	391
1861	58¾	60⅞	2⅛	30½	33⅝	3⅛	6,472	6,937	465
1862	52⅜	54¼	1⅞	31⅝	33⅛	1½	6,273	6,529	256
1863	61¾	65⅞	4⅛	32	34¾	2¾	6,791	7,323	532
1864	63¾	63⅜	–0⅜	34⅞	37¼	2⅜	7,225	7,469	244
1865	49	51⅝	2⅝	22½	24⅞	2⅜	5,075	5,469	394
1866	50⅝	56¾	6⅛	27⅜	28¼	0⅞	5,704	6,117	413
1867	47⅛	49½	2⅜	25½	28⅜	2⅞	5,304	5,753	449
Total ..	523⅜	551⅛	27¾	287⅝	315⅝	28	59,458	64,020	4,562
Average	52⅜	55⅛	2¾	28¾	31½	2¾	5,946	6,402	456

salts. The two Plots, 4 A and 4 AA, have received the same description and amount of mineral manure every year from the commencement. In addition, 4 A has received 200 lbs. of ammonia-salts per acre every year, but 4 AA 400 lbs., or double the amount the first 6 years, and only 200 lbs., or the same as 4 A, the next 10 years. Any increase, therefore, on Plot 4 AA over 4 A, during the 10 years in which they both received the same amount of ammonia-salts, may presumably be attributed to the extra amount applied to 4 AA during the first 6 years. For the sake of more exact comparison than the record of the actual quantities of dressed corn would afford, the total corn per acre has, in each case, been calculated into bushels of 52lbs.

It appears that, during the 10 years, there was an excess of produce on 4 AA compared with 4 A, due to the unexhausted residue from the previous nitrogenous manuring, of nearly 28 bushels of corn, and just 28 cwts. of straw; or an annual average of 2¾ bushels of corn, and 2¾ cwts. of straw. It is also to be observed that the excess in the tenth year was almost exactly the same as the average of the 10 years, showing that the residue was not even then exhausted. There was, then, in this case, a marked effect upon the succeeding barley crops, from the extra ammonia-salts applied in the first 6 years.

Table XLI. (page 128) shows, in like manner, the effects on succeeding barley-crops of a previous extra supply of nitrogen in the form of nitrate of soda. The two Plots, 1 N and 2 N, each received in the first year, 1852, 3½ cwts. superphosphate of lime, and 300 lbs. sulphate of potass per acre. Each year since, 1 N has received 275 lbs. nitrate of soda, and 2 N 550 lbs. during the first 5 years, but subsequently only 275 lbs., or the same amount as 1 N.

The Table shows that, during the 14 years after the cessation of the extra application of nitrate on Plot 2 N, it continued to give more produce than 1 N, amounting in the 14 years to about 51½ bushels of corn, and rather over 30 cwts. of straw, or to an average per acre per annum of 3⅝ bushels of corn, and 2⅛ cwts. of straw. Here, again, as in the experiments with the ammonia-salts, the increase in the last year of the series is almost precisely the same as the average increase over the whole period. The differences from year to year are obviously due to peculiarities of season. The result is clear, however, that with the nitrate, as with the ammonia-salts, there was a somewhat lasting effect from the extra amount applied during the earlier years.

It will be of much interest to compare the above results with barley, with those obtained with wheat; and it is especially desirable to adduce those which bear upon the point relating to

TABLE XLI.—Effects of the Unexhausted Residue of Nitrogen applied to Barley as Nitrate of Soda.

YEARS.	PRODUCE PER ACRE.								
	TOTAL CORN IN BUSHELS OF 52 lbs.			STRAW (and Chaff).			TOTAL PRODUCE (Corn and Straw)		
	Plot 1 N. 275 lbs. Nitrate Soda, 19 Years, 1853–'71.	Plot 2 N. 550 lbs. Nitrate Soda, 5 Years, 1853–'57; 275 lbs., 14 Years, 1858–'71.	2 N, over (or under –) 1 N.	Plot 1 N. 275 lbs. Nitrate Soda, 19 Years, 1853–'71.	Plot 2 N. 550 lbs. Nitrate Soda, 5 Years, 1853–'57; 275 lbs., 14 Years, 1858–'71.	2 N, over (or under –) 1 N.	Plot 1 N. 275 lbs. Nitrate Soda, 19 Years, 1853–'71.	Plot 2 N. 550 lbs. Nitrate Soda, 5 Years, 1853–'57; 275 lbs., 14 Years, 1858–'71.	2 N, over (or under –) 1 N.
	Bushels.	Bushels.	Bushels.	Cwts.	Cwts.	Cwts.	lbs.	lbs.	lbs.
Average, 5 years, 1853–'57	$45\frac{3}{8}$	$51\frac{1}{4}$	$5\frac{7}{8}$	$25\frac{1}{2}$	$31\frac{1}{2}$	6	5,226	6,198	972
1858	$41\frac{1}{8}$	$47\frac{5}{8}$	$6\frac{1}{2}$	$20\frac{1}{8}$	$23\frac{5}{8}$	$3\frac{1}{2}$	4,399	5,125	726
1859	$26\frac{7}{8}$	$29\frac{1}{4}$	$2\frac{3}{8}$	$18\frac{3}{4}$	$21\frac{1}{4}$	$2\frac{1}{2}$	3,500	3,905	405
1860	$29\frac{5}{8}$	$32\frac{3}{4}$	$3\frac{1}{8}$	$16\frac{3}{4}$	$18\frac{5}{8}$	$1\frac{7}{8}$	3,416	3,793	377
1861	$42\frac{5}{8}$	$45\frac{1}{8}$	$2\frac{1}{2}$	$27\frac{1}{4}$	$29\frac{5}{8}$	$2\frac{3}{8}$	5,260	5,665	405
1862	$39\frac{7}{8}$	42	$2\frac{1}{8}$	$24\frac{1}{4}$	$24\frac{3}{4}$	$\frac{1}{2}$	4,793	4,959	166
1863	$55\frac{1}{4}$	58	$2\frac{3}{4}$	$30\frac{1}{4}$	$29\frac{7}{8}$	$-\frac{3}{8}$	6,265	6,366	101
1864	$45\frac{3}{8}$	$52\frac{1}{8}$	$6\frac{3}{4}$	$24\frac{1}{8}$	$27\frac{3}{4}$	$3\frac{5}{8}$	5,065	5,820	755
1865	$40\frac{3}{8}$	$42\frac{3}{4}$	$2\frac{3}{8}$	$18\frac{1}{2}$	$21\frac{1}{2}$	3	4,174	4,629	455
1866	$36\frac{3}{4}$	$43\frac{1}{2}$	$6\frac{3}{4}$	$21\frac{1}{8}$	$23\frac{7}{8}$	$2\frac{3}{4}$	4,275	4,941	666
1867	$35\frac{7}{8}$	$38\frac{5}{8}$	$2\frac{3}{4}$	$21\frac{1}{8}$	$21\frac{3}{4}$	$\frac{5}{8}$	4,234	4,438	204
1868	$27\frac{1}{8}$	$27\frac{3}{4}$	$0\frac{5}{8}$	$18\frac{7}{8}$	$17\frac{1}{8}$	$-1\frac{3}{4}$	3,530	3,366	–164
1869	$39\frac{5}{8}$	$42\frac{5}{8}$	3	24	$27\frac{5}{8}$	$3\frac{3}{8}$	4,759	5,313	554
1870	$37\frac{3}{4}$	$43\frac{3}{4}$	6	$13\frac{1}{4}$	$19\frac{1}{8}$	$5\frac{7}{8}$	3,456	4,413	957
1871	$47\frac{1}{8}$	$50\frac{7}{8}$	$3\frac{3}{4}$	$29\frac{1}{4}$	$31\frac{1}{2}$	$2\frac{1}{4}$	5,726	6,175	449
Total ..	$545\frac{3}{8}$	$596\frac{3}{4}$	$51\frac{3}{8}$	$307\frac{5}{8}$	338	$30\frac{3}{8}$	62,852	68,908	6,056
Average	39	$42\frac{5}{8}$	$3\frac{5}{8}$	22	$24\frac{1}{8}$	$2\frac{1}{8}$	4,489	4,922	433

the latter crop, since we are now enabled to give them for 8 years longer than at the time of the last Report.

Plots 5 and 16, referred to in Table XLII. (next page), were both varioulsy manured during the first 8 years, 1844–1851. From 1852 to the present time, Plot 5 has every year received a mixed mineral manure containing superphosphate of lime, and sulphates of potass, soda, and magnesia; whilst Plot 16 received annually, for the first 13 years of the period, namely 1852–1864 inclusive, the same mixed mineral manure as Plot 5, but in addition the very excessive amount of 800 lbs. of ammonia-salts per acre per annum. For the crop of 1865, and since, however, Plot 16 has been left unmanured. The 800 lbs. of ammonia-salts would supply annually to the soil about 200 lbs. of ammonia = 164 lbs. of nitrogen; whilst, as will be seen further on, scarcely three-tenths as much was recovered in the average annual increase of wheat (corn and straw) during the 13 years of the application;

so that at the end of that period there remained seven-tenths, or more, of the large amount applied still to be accounted for.

TABLE XLII.—Effects of the Unexhausted Residue of Nitrogen applied to Wheat as Ammonia-salts.

Years.	PRODUCE PER ACRE.								
	TOTAL CORN IN BUSHELS OF 61 lbs.			STRAW (and Chaff).			TOTAL PRODUCE (Corn and Straw).		
	Plot 5. Mixed Mineral Manure alone, 20 Years, 1852–'71.	Plot 16. Mixed Mineral Manure, and 800 lbs. Ammonia-salts, 13 Years, 1852–'64; Unmanured since.	Plot 16, over (or under −) Plot 5.	Plot 5. Mixed Mineral Manure alone, 20 Years, 1852–'71.	Plot 16. Mixed Mineral Manure, and 800 lbs. Ammonia-salts, 13 Years, 1852–'64; Unmanured since.	Plot 16, over (or under −) Plot 5.	Plot 5. Mixed Mineral Manure alone, 20 Years, 1852–'71.	Plot 16. Mixed Mineral Manure, and 800 lbs. Ammonia-salts, 13 Years, 1852–'64; Unmanured since.	Plot 16, over (or under −) Plot 5.
	Bushels.	Bushels.	Bushels.	Cwts.	Cwts.	Cwts.	lbs.	lbs.	lbs.
Average, 13 years, 1852–'64	18⅞	40⅞	22	16½	46⅝	30⅛	3,009	7,713	4,704
1865	15	34¾	19¾	10½	25¾	15¼	2,091	5,007	2,916
1866	13⅝	18⅜	4¾	13⅛	17½	4⅜	2,303	3,081	778
1867	9½	14¾	5¼	9¼	14⅜	5⅛	1,613	2,512	899
1868	18½	23⅞	5⅜	12	18¼	6¼	2,481	3,503	1,022
1869	15⅜	16⅜	1	14¼	14¾	0½	2,543	2,647	104
1870	19⅝	19¾	0⅛	12⅛	12	−0⅛	2,564	2,557	−7
1871	12⅝	13¾	1⅛	12⅞	13¾	0⅞	2,207	2,380	173
Total ..	104¼	141⅝	37⅜	84⅛	116⅜	32¼	15,802	21,687	5885
Average	14⅞	20¼	5⅜	12	16⅝	4⅝	2,257	3,098	841

Stated broadly and in round numbers, the result is as follows:—By the actual utilization, or appropriation, of say three-tenths of the nitrogen annually supplied, there was obtained, over the 13 years of the application, an average produce of nearly 41 bushels of wheat grain, and more than 46½ cwts. of straw, or an average annual increase over the produce by the mixed mineral manure alone, during the same period, of 22 bushels of grain and 30 cwts. of straw. During the 7 succeeding years, the seven-tenths of the supplied nitrogen, which was not thus recovered in the increase of crop in the years of its application, yielded an average annual produce of only 20¼ bushels of grain and 16⅝ cwts. of straw, or an average annual increase over the produce by the mineral manure alone (Plot 5) of only 5½ bushels of grain and 4⅝ cwts. of straw; whilst during the last 3 years there was scarcely any increase at all. In fact, of the 13 years application, and the 13 years unrecovered nitrogen, amounting to about seven-tenths of the whole supplied, less than the quantity left unrecovered in one year, was effective during the 7 succeeding years; and, practically speaking, nearly the whole of the result was obtained during the first 4 years of the 7. It is true that the mixed mineral manure was not applied on Plot 16 as on Plot 5 during the last 7 years; but with the liberal application during the 13 years and previously, there could be no want of available mineral constituents within the soil; and even if the produce during the 7 years were compared with that without any manure, instead of with that with mineral manure, the annual increase from the residue would appear but little more, and the general result would remain substantially the same.

Again, Plots 5, and 17 and 18, particulars of which are given in Table XLIII. (next page), received during the first 8 years (1844–'51) various, but, upon the whole, very similar mixtures of mineral manures, ammonia-salts, and rape-cake; and, as the Table shows, they yielded very similar average annual amounts of produce during that period. In 1852, therefore, the plots were, practically, in very similar condition. For the produce of that year, and each year since, up to the present time, Plot 5 has received a mixture of superphosphate of lime, and sulphates of potass, soda, and magnesia. Over the same period, Plots 17 and 18 have received the same mineral manure, or ammonia-salts, alternately. For example, for the crop of 1852, Plot 17 received 400 lbs. ammonia-salts, and Plot 18 the mineral manure; for that of 1853, Plot 17 received the mineral manure, and Plot 18 the ammonia-salts; and so on, alternately, for the 20 years. Thus, in each year, the one or the other plot was manured with mineral manure, succeeding a dressing of ammonia-salts. These were conditions obviously very favourable for turning to account any residue of the nitrogenous manure of the previous year which might still remain in the soil in a state of combination, and distribution, such as to be available for the plant. The Table shows the produce obtained each year on Plot 5 by mineral manure year after year, and also that obtained each year by mineral manures after ammonia-salts, on Plot 17, or 18, as the case may be.

It is seen that the mineral manure on Plot 17, or 18, each year succeeding a liberal dressing of ammonia-salts for the crop of the previous year, gave, in 20 years, only $16\frac{3}{8}$ bushels of corn and $22\frac{1}{8}$ cwts. of straw, or annually only $\frac{3}{4}$ bushel of corn and $1\frac{1}{8}$ cwt. of straw, more than Plot 5, which received the same mineral manure every year without the interposition of any ammonia-salts.

The result is, then, that when 400 lbs. of ammonia-salts per acre were used for wheat, the unexhausted residue of nitrogen, if any, gave very little increase of produce in succeeding years;

TABLE XLIII.—Effects of the Unexhausted Residue of Nitrogen applied to Wheat as Ammonia-salts.

Years.	PRODUCE PER ACRE. Total Corn in Bushels of 61 lbs.			Straw (and Chaff).			Total Produce (Corn and Straw).		
	Plot 5. Mixed Mineral Manure alone, 20 Years, 1852–'71.	Plots 17 or 18. Mixed Mineral Manure, every Year succeeding 400 lbs. Ammonia-salts; 20 Years, 1852–'71.	Plots 17 or 18, over (or under −) Plot 5.	Plot 5. Mixed Mineral Manure alone, 20 Years, 1852–'71.	Plots 17 or 18. Mixed Mineral Manure, every Year succeeding 400 lbs. Ammonia-salts; 20 Years, 1852–'71.	Plots 17 or 18, over (or under −) Plot 5.	Plot 5. Mixed Mineral Manure alone, 20 Years, 1852–'71.	Plots 17 or 18. Mixed Mineral Manure, every Year succeeding 400 lbs. Ammonia-salts; 20 Years, 1852–'71.	Plots 17 or 18, over (or under −) Plot 5.
	Bushels.	Bushels.	Bushels.	Cwts.	Cwts.	Cwts.	lbs.	lbs.	lbs.
Average, 8 Years, 1844–'51	$31\frac{1}{4}$	32	$0\frac{3}{4}$	$28\frac{3}{4}$	$29\frac{3}{4}$	1	5,122	5,280	158
1852	$17\frac{1}{8}$	$14\frac{5}{8}$	$-2\frac{1}{2}$	$17\frac{5}{8}$	$15\frac{3}{8}$	$-2\frac{1}{4}$	3,019	2,621	−398
1853	$9\frac{3}{4}$	$8\frac{5}{8}$	$-1\frac{1}{8}$	$18\frac{1}{4}$	$17\frac{7}{8}$	$-0\frac{3}{8}$	2,640	2,534	−106
1854	$25\frac{1}{2}$	$24\frac{7}{8}$	$-0\frac{5}{8}$	$22\frac{3}{8}$	$21\frac{3}{8}$	−1	4,067	3,917	−150
1855	$18\frac{3}{4}$	$19\frac{1}{8}$	$0\frac{3}{8}$	$16\frac{1}{8}$	$16\frac{7}{8}$	$0\frac{3}{4}$	2,960	3,059	99
1856	$19\frac{3}{4}$	$18\frac{5}{8}$	$-1\frac{1}{8}$	$18\frac{1}{2}$	$17\frac{5}{8}$	$-0\frac{7}{8}$	3,274	3,111	−163
1857	$23\frac{7}{8}$	$26\frac{3}{8}$	$2\frac{1}{2}$	15	$17\frac{7}{8}$	$2\frac{7}{8}$	3,137	3,612	475
1858	$19\frac{3}{4}$	23	$3\frac{1}{4}$	$14\frac{1}{8}$	$17\frac{3}{4}$	$3\frac{5}{8}$	2,795	3,393	598
1859	$20\frac{7}{8}$	$19\frac{3}{4}$	$-1\frac{1}{8}$	$21\frac{1}{8}$	$21\frac{5}{8}$	$0\frac{1}{2}$	3,633	3,636	3
1860	15	$15\frac{1}{2}$	$0\frac{1}{2}$	$14\frac{1}{2}$	$15\frac{1}{2}$	1	2,539	2,678	139
1861	$17\frac{3}{8}$	$19\frac{5}{8}$	$2\frac{1}{4}$	$13\frac{7}{8}$	$15\frac{1}{4}$	$1\frac{3}{8}$	2,616	2,906	290
1862	$18\frac{1}{8}$	$19\frac{3}{8}$	$1\frac{1}{4}$	$16\frac{1}{2}$	$18\frac{1}{2}$	2	2,960	3,248	288
1863	$21\frac{1}{8}$	$22\frac{5}{8}$	$1\frac{1}{2}$	$15\frac{3}{8}$	17	$1\frac{5}{8}$	3,017	3,290	273
1864	$17\frac{3}{4}$	$18\frac{3}{8}$	$0\frac{5}{8}$	$12\frac{1}{4}$	$13\frac{5}{8}$	$1\frac{3}{8}$	2,462	2,654	192
1865	15	18	3	$10\frac{1}{2}$	$13\frac{1}{8}$	$2\frac{5}{8}$	2,091	2,568	477
1866	$13\frac{5}{8}$	$13\frac{1}{4}$	$-0\frac{3}{8}$	$13\frac{1}{8}$	$13\frac{1}{2}$	$0\frac{3}{8}$	2,303	2,328	25
1867	$9\frac{1}{2}$	$10\frac{7}{8}$	$1\frac{3}{8}$	$9\frac{1}{4}$	11	$1\frac{3}{4}$	1,613	1,893	280
1868	$18\frac{1}{2}$	$19\frac{3}{4}$	$1\frac{1}{4}$	12	$14\frac{3}{8}$	$2\frac{3}{8}$	2,481	2,807	326
1869	$15\frac{3}{8}$	$16\frac{1}{2}$	$1\frac{1}{8}$	$14\frac{1}{4}$	$15\frac{1}{8}$	$0\frac{7}{8}$	2,543	2,705	162
1870	$19\frac{5}{8}$	$20\frac{1}{2}$	$0\frac{7}{8}$	$12\frac{1}{8}$	$12\frac{1}{4}$	$0\frac{1}{8}$	2,564	2,628	64
1871	$12\frac{5}{8}$	16	$-3\frac{3}{8}$	$12\frac{7}{8}$	$16\frac{1}{4}$	$3\frac{3}{8}$	2,207	2,797	590
Total ..	349	$365\frac{3}{8}$	$16\frac{3}{8}$	$299\frac{3}{4}$	$321\frac{7}{8}$	$22\frac{1}{8}$	54,921	58,385	3464
Average	$17\frac{1}{2}$	$18\frac{1}{4}$	$0\frac{3}{4}$	15	$16\frac{1}{8}$	$1\frac{1}{8}$	2,746	2,919	173

whereas, when the same amount of ammonia-salts was used for 6 years in succession for barley, there was an excess of produce, doubtless due to the unexhausted residue of nitrogen, which averaged $2\frac{3}{4}$ bushels of corn, and $2\frac{3}{4}$ cwts. of straw, per acre per annum, for 10 years in succession, with evidence that the effect was not even then at an end.

Thus, it was shown in Sections II. and III. that a given amount of nitrogen in manure yielded more increase of barley than of wheat in the years of its application; and it is now seen that it also leaves a more effective residue when applied for barley than for wheat.

The questions arise—What proportion of the supplied nitrogen is, in either case, recovered in the increase of crop? What becomes of the unrecovered amount, if any? How is it that more increase is obtained, and that there is apparently less loss, in the case of the barley than of the wheat?

In our first paper in the 'Journal of the Royal Agricultural Society of England,' now more than twenty-five years ago, we pointed out that about 5 lbs. of ammonia in manure had been found necessary for the production of 1 bushel of increase of wheat and its straw. Frequently since, the question of the proportion of the nitrogen of manure recovered in the increase of produce obtained has been illustrated by results of the direct analysis of the produce. This was done, so far as barley is concerned, in the Report on the first 6 years of the experiments (Vol. xviii., 1858). In a paper "On the Annual Yield of Nitrogen per Acre in Different Crops," read at the meeting of the British Association for the Advancement of Science held at Leeds in 1858, it was concluded that, with wheat and barley indifferently, rather more than four-tenths of the supplied nitrogen was recovered in the increase. Again, in a paper "On the Sources of the Nitrogen of Vegetation, &c.,"* much the same estimate was arrived at for wheat, for barley, and for meadow-hay; and estimates were also made in regard to some other crops.

The subject is, however, one of such great importance, and the number of years over which the estimate can be made is now so much greater than formerly, that numerous new analyses have been made for the purposes of this paper. The nitrogen has thus been determined in the produce for 20 years (1852-1871), of six of the wheat, and five of the barley plots; also, but for 3 years only, in that of three of the experimental oat plots. For the oats the nitrogen has been determined in the grain and in the straw of each year separately; but, for the wheat, and for the barley, respectively, a mixture has been made of the produce (corn and the straw separately) of each plot, for the 20 years, the quantity taken being in exact proportion to the amount of produce per acre each year. The whole was then ground up together; so that the mixed samples respectively represent the produce of the grain and of the straw of each plot, for the 20 years.

Table XLIV. (p. 133) shows the amount of nitrogen recovered in the increase of produce (corn and straw), and the amount not recovered, for 100 supplied in manure.

For *wheat*, the plots selected are—that with 14 tons farmyard

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* 'Philosophical Transactions,' Part II., 1861; also 'Jour. Chem. Soc.,' new series, vol. i., 1863.

TABLE XLIV.—Nitrogen Recovered, and not Recovered, in Increase of Produce, for 100 supplied in Manure.

Plots.	MANURES PER ACRE, PER ANNUM.	FOR 100 NITROGEN IN MANURE. Recovered in Increase.	FOR 100 NITROGEN IN MANURE. Not Recovered in Increase.
	Wheat—20 Years, 1852–1871.		
6	Mixed Mineral Manure and 200 lbs. Ammonia-salts (= 41 lbs. Nitrogen)	32·4	67·6
7	Mixed Mineral Manure and 400 lbs. Ammonia-salts (= 82 lbs. Nitrogen)	32·9	67·1
8	Mixed Mineral Manure and 600 lbs. Ammonia-salts (= 123 lbs. Nitrogen)	31·5	68·5
16	Mixed Mineral Manure and 800 lbs. (1) Ammonia-salts (= 164 lbs. Nitrogen)	28·5	71·5
9 A	Mixed Mineral Manure and 550 lbs. (2) Nitrate Soda (= 82 lbs. Nitrogen)	45·3	54·7
2	14 tons Farmyard Manure every year.	14·6	85·4
	Barley—20 Years, 1852–1871.		
4 A	Mixed Mineral Manure and 200 lbs. Ammonia-salts (= 41 lbs. Nitrogen)	48·1	51·9
4 AA	Mixed Mineral Manure and { 400 lbs. Ammonia-salts (= 82 lbs. Nitrogen) 6 years, 1852–'57 .. 200 lbs. Ammonia-salts (= 41 lbs. Nitrogen) 10 years, 1858–'67 .. 275 lbs. Nitrate Soda (= 41 lbs. Nitrogen) 4 years, 1868–'71 .. }	49·8	50·2
4 C	Mixed Mineral Manure and { 2000 lbs. Rape-cake (= 95 lbs. Nitrogen) 6 years, 1852–'57 .. 1000 lbs. Rape-cake (= 47·5 lbs. Nitrogen) 14 years, 1858–'71 .. }	36·3	63·7
7	14 tons Farmyard Manure every year.	10·7	89·3
	Oats—3 Years, 1869–1871.		
4	Mixed Mineral Manure and 400 lbs. Ammonia-salts (= 82 lbs. Nitrogen)	51·9	48·1
6	Mixed Mineral Manure and 550 lbs. Nitrate Soda (= 82 lbs. Nitrogen)	50·4	49·6

(1) 13 years only, 1852–1864. (2) 475 lbs. Nitrate = 71 lbs. Nitrogen in 1852; 275 lbs. = 41 lbs. Nitrogen in 1853 and 1854; 550 lbs. = 82 lbs. Nitrogen each year afterwards.

manure per acre per annum for 20 years; those with mixed mineral manure and 200 lbs., 400 lbs., 600 lbs., and 800 lbs., of ammonia-salts, per acre per annum; and that with the same mineral manure and 550 lbs. nitrate of soda per acre per annum.

For *barley*, the plots are—that with 14 tons farmyard manure per acre per annum for 20 years; that with the same mixed mineral manure as for the wheat, and 200 lbs. ammonia-salts per acre per annum for 20 years; that with the same mineral manure for 20 years, 400 lbs. ammonia-salts for the first 6 years, 200 lbs. for the next 10 years, and 275 lbs. nitrate of soda for the last 4 years of the 20; and that with the same mineral manure and 2000 lbs. rape-cake for the first 6 years, and 1000 lbs. for the next 14 years.

For *oats*—the plot with the same mixed mineral manure as for wheat and for barley, and 400 lbs. ammonia-salts; also that with the same mineral manure and 550 lbs. nitrate of soda per acre per annum, but for three years only.

The increase in the amount of nitrogen in the produce by the use of it in manure is, in the cases of the artificial mixtures of nitrogenous and mineral manure, calculated over the amount determined in the produce by the corresponding mineral manure without ammonia. The increase in the produce of nitrogen by farmyard manure is also calculated over that by the purely mineral manure.

According to the figures, there was, with the same mixed mineral manure and 200 lbs. of ammonia-salts per acre per annum for 20 years in succession, rather less than one-third of the supplied nitrogen recovered in the increase of the wheat, but nearly one-half in that of the barley.

With the same mineral manure, and 400 lbs. ammonia-salts applied for 20 years for wheat, and 400 lbs. for 6 years, 200 lbs. for 10 years, and 275 lbs. nitrate for 4 years—in all 20 years—for barley, there was recovered in the increase of the wheat, again scarcely one-third, but in that of the barley again nearly one-half. With the same mineral manure and 400 lbs. ammonia-salts applied to oats, but for 3 years only, there was even rather more than one-half of the supplied nitrogen reckoned to be recovered in the increase of crop.

When the more excessive amounts of ammonia-salts were applied for wheat, notably less than one-third of the supplied nitrogen was recovered, and the less the greater the excess.

On the other hand, when 550 lbs. of nitrate of soda (containing nitrogen = 400 lbs. ammonia-salts) were applied, there was, even with wheat, not much less than half, and with oats rather more than half of the nitrogen recovered in the increase of crop.

With rape-cake applied for barley, a considerably less proportion of the nitrogen was recovered than with ammonia-salts.

Lastly, with farmyard manure, whether applied to wheat or to barley, very much less of the supplied nitrogen was recovered than with any of the artificial manures. Indeed, assuming the dung to have provided about 200 lbs. of nitrogen per acre per annum, there was recovered in the increased produce of the wheat only about one-seventh, and in that of the barley scarcely one-ninth, of the nitrogen supplied by the manure.

The general result of this new and more extended inquiry is, then—that with neither crop is the whole of the supplied nitrogen recovered in the increase of produce obtained; that when a given amount of ammonia-salts was applied a much less proportion was recovered in wheat than in either barley or oats; but that, even with wheat, more was recovered when nitrate of soda was employed than when ammonia-salts were used.

How is the apparent loss to be explained? and how is it that a greater loss is observed with wheat than with either barley or oats?

In the paper in the 'Philosophical Transactions' (Part II. 1861),* already referred to, after showing the relation of the nitrogen in increase to that in manure in some particular cases, we submitted the following questions:—

"Is the unrecovered amount of supplied Nitrogen or at any rate a considerable proportion of it, drained away and lost?

"Are the nitrogenous compounds transformed within the soil, and their Nitrogen, in some form, evaporated?

"Does the missing amount for the most part remain in some fixed combination in the soil, only to be yielded up, if ever, in the course of a long series of years?

"Is ammonia itself, or Nitrogen in the free state, or in some other form of combination than ammonia, given off from the surface of the growing plant? Or, lastly,

"When Nitrogen is supplied within the soil for the increased growth of the Graminaceous crop, is there simply an unfavourable distribution of it, considered in relation to the distribution of the underground feeders of the crop?—the Leguminous crop, which alternates with it, gathering from a more extended range of soil, and leaving a residue of assimilable Nitrogen within the range of collection of a next succeeding Cereal one?"

Briefly enumerated, the three main sources of loss of nitrogen here suggested are, then—*drainage; accumulation within the soil in a state of combination, or distribution, unfavourable for being taken up by the immediately succeeding crop; or evolution in some form from the surface of the growing plant.*

From some of the results reported in the same paper, and also

* "On the Sources of the Nitrogen of Vegetation; with special reference to the question whether plants assimilate free or uncombined Nitrogen." By Lawes, Gilbert, and Pugh.

from other considerations, we concluded, in opposition to the view we had previously been disposed to entertain, that the last-named of these, that is, *evolution from the plant*, did not take place.

With regard to *drainage*, the previous results of Professor Way,* and especially the subsequent ones of the experiments conducted at Rugby under our superintendence for the Royal Sewage Commission,† led us to attribute great importance to that part of the subject. In the course of that inquiry we arranged for the collection of sixty-two samples of drainage-water, the partial analysis of which was conducted by Professor Way; and, comparing the results with those on the corresponding samples of sewage, it was obvious that but a small proportion of the nitrogen of the sewage which was not obtained in the increase of produce was recovered in the drainage-water in the form of ammonia. We therefore arranged for the collection of some special samples for complete analysis, and especially for the determination of the nitric acid, if any, in both sewage and drainage-water. The results showed considerably more nitrogen in the drainage in the form of nitric acid than in that of ammonia. Indeed, it was obvious that a large proportion of that important manurial constituent of the sewage was drained away and lost. Satisfied for the time with this indication, it was not contemplated to follow up that part of our general inquiry until the question of the accumulation of nitrogen within the soil itself had first been investigated.

After the publication, in 1864, of the results of the growth of wheat for twenty years in succession on the same land, the subject of the composition of the crop, according to season and manure, was resumed; and it was determined to examine both the soils and the drainage-waters from the different plots, to see whether there was, on the one hand an accumulation of nitrogen in the soil, and on the other a loss by drainage. The nitrogen was determined in the first 9 inches, the second 9 inches, and the third 9 inches; or, in all, to a depth of 27 inches of soil. The results were given at the Meeting of the British Association for the advancement of Science at Nottingham, in 1866, and the following quotation from the abstract of that paper will indicate their general bearing:—

"The accumulation of nitrogen from the residue of manuring

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* "On the Composition of the Waters of Land-Drainage and of Rain." ('Journal of the Royal Agricultural Society of England,' vol. xvii. Part I.)

† "On the Sewage of Towns" (Third Report and Appendices 1, 2, and 3, of the Royal Commission, 1865). Also—"On the Composition, Value, and Utilisation of Town Sewage" ('Journal of the Chemical Society,' New Series, vol. iv.; entire series, vol. xix., 1866).

was found to be, in some cases, very considerable; but even with equal amounts supplied, it varied, both in total amount and in distribution, according to circumstances, the depth to which the unused supply had penetrated being apparently influenced by the character and amount of the associated manurial constituents. The general result was, that, although a considerable amount of the nitrogen supplied in manure which had not been recovered as increase of crop was shown to remain in the soil, still a larger amount was as yet unaccounted for. Initiative results indicated that some existed as nitric acid in the soil, but it was believed that the amount so existing would prove to be but small. In fact, it was concluded that a considerably larger proportion would remain entirely unaccounted for within the soil to the depth under examination than was there traceable, and the probability was, that at any rate some of this had passed off into the drains, and some into the lower strata of the soil."

It was at the same time shown, by reference to field results, how very small was the increase of subsequent wheat crops due to the large residue of nitrogen accumulated in the soil, notwithstanding its amount was many times greater than that which would yield an increase of 20 bushels or more, if applied afresh to soil otherwise in the same condition.

Thus, then, it was established, that there was a considerable accumulation within the soil, of nitrogen supplied in manure and not recovered in the increase of the crop, but that there remained a considerable quantity not so accounted for; and it was concluded that some of this had passed off into the drains, and some into the lower strata of the subsoil.

Being fully occupied at the time with other subjects, and finding that Dr. Voelcker was desirous to investigate the question of land drainage, we gladly provided him with samples of the drainage-water from the differently-manured plots in the experimental wheat-field, and also with full particulars of their history for the purposes of inquiry. In the 'Journal of the Chemical Society of London' (vol. ix. s.s. p. 291, 1871), Dr. Voelcker has published the results of the complete analysis of seventy samples of drainage-water of accurately known history so collected. Those results are a most valuable contribution to our knowledge of the subject, not only in its agricultural bearings, but also in relation to the question of the influence of the sources of potable and other waters upon their composition and quality. For the details we must refer the reader to Dr. Voelcker's own paper; but the following table gives a summary of the results so far as they relate to the loss by drainage of the nitrogen supplied to the soil by manure.

TABLE XLV.—Composition of Drainage-water from Plots differently Manured; Broadbalk Field, Rothamsted; Wheat every Year, commencing 1844.

Nitrogen as Nitrates and Nitrites, per 100,000 parts of Water.
Dr. VOELCKER's Results.

DATES OF COLLECTION, &c.	MANURES PER ACRE, PER ANNUM.						
	14 Tons Farmyard Manure, every Year.	Without Manure, every Year.	Sulphate of Potass, Soda, and Magnesia and Superphosphate of Lime.				
			Without Nitrogen in Manure since 1851.	And 41 lbs. Nitrogen as Ammonia-salts.	And 82 lbs. Nitrogen as Ammonia-salts.	And 123 lbs Nitrogen as Ammonia-salts.	And 82 lbs. Nitrogen as Nitrate Soda.
	Plot 2.	Plots 3–4.	Plot 5.	Plot 6.	Plot 7.	Plot 8.	Plot 9.
Dec. 6, 1866, full flow ..	1·956	0·648	0·878	1·330	2·170	2·567	0·707
May 21, 1867, full flow ..	..	0·052	0·059	0·089	0·078	0·274	0·785
Jan. 13, 1868, full flow ..	1·256	0·667	0·926	1·704	2·811	3·104	1·196
Apr. 21, 1868, full flow ..	..	0·085	0·137	0·189	0·448	0·578	5·830
Dec. 29, 1868, enormous flow	..	0·500	0·530	0·952	1·493	1·874	0·659
Means	1·606	0·390	0·506	0·853	1·400	1·679	1·835

The conditions under which the results given in the above (and the next) Table have been obtained, should be further described as follows:—With the exception of Plot 9, as explained below, each plot has been manured as stated in the Table every year, commencing 1852. Further, Plot 2 received 14 tons of farmyard manure every year, commencing 1843-4. The unmanured portion consists of two lands, Plots 3 and 4 respectively, the drain running under the furrow which separates them; Plot 3 has been unmanured since the commencement of the experiments in 1843-4, and for some years previously; whilst Plot 4 has only been unmanured since 1851; for which, and six preceding seasons, it received ammonia-salts and superphosphate of lime; the effects of the unexhausted residue from which are slightly apparent even up to the present time. Each of the other plots consists of two lands, the drain running under the separating furrow. For the crop of 1851, and several preceding seasons, Plot 5 received, besides mineral manure, ammonia-salts in rather heavy dressings, and also some rape-cake. The other plots also received various amounts of nitrogenous and mineral manure in 1851, and previously. Only one of the two lands comprising Plot 9 has received the mineral manure stated (commencing 1855); the other has had the nitrate alone: the quantity of nitrate applied over the two lands was equal to only 71 lbs. nitrogen per acre in 1852, and to only 61 lbs. in 1853 and 1854, but to 82 lbs. in each year since.

In the first place it will be observed that, in three of the five occasions on which all the other drains ran freely, no result is given for the farmyard manure plot. The fact is that, whilst the pipe-drains from every one of the other plots in the experimental wheat-field run *freely*, perhaps four or five or more times annually, the drain from the dunged plot seldom runs at all more than once a year, and in some seasons not at all. We must refer to a former paper * for some further particulars relating to this very important result. Stated briefly, it was found that the dunged soil, when saturated, retained, within 12 inches from the surface, an excess of water which would be equivalent to about 1½ inch of rain more than that held to the same depth on the unmanured and the artificially manured plots in the same field. The conclusion is obvious, that the dunged soil, with its vast accumulation of organic matter, and doubtless greater degree of disintegration, porosity, and power of absorption, especially near the surface, is enabled to retain much more water. Hence a much greater amount and continuity of rain is required to overcome its power of retention, and to reach the drains in its case. This result is one of very great interest and significance. Thus, whether the porosity of a clay soil be increased by the application of manure, by mechanical means, or by a combination of the two, its power to absorb and retain water, in an available and not injurious state, will be proportionately increased; and, not only will the growing crops be thereby rendered more independent of drought, but the necessity for artificial drainage will, at any rate in some soils, be greatly lessened.

Not only does the drain-pipe from the dunged plot seldom run, but it will be observed that the proportion of nitrogen in its drainage water is, in one of the cases given, less than where 82 lbs. of nitrogen were supplied as ammonia-salts, and in the other less than where 41 lbs. of nitrogen were so supplied. This is the case though the dung is estimated to supply to the soil nearly, if not quite, 200 lbs. of nitrogen per acre per annum. In connection with this point it may be stated that analysis of the soil of the dunged plot after 25 years of the application of the manure, showed that the top 9 inches contained nearly twice as high a percentage of nitrogen as the corresponding layer of any of the artificially manured plots. Yet, not once during the 29 years of the experiments has the farmyard-manured plot yielded as high a total produce (corn and straw together) as one or other of the plots manured with mixed mineral manure and ammonia salts or

* 'Journal of the Royal Agricultural Society of England,' vol. vii. s.s., Part I., p. 115.

nitrate of soda. It is obvious, that the nitrogen supplied by the dung is retained by the soil in a condition not only much less rapidly available to growing crops, but also much less liable to loss by drainage. Still, there is a large amount of the nitrogen supplied in the dung not yet satisfactorily accounted for.

The Table shows that at each period of collection there was less nitrogen in the drainage-water from the plot the whole of which has been unmanured since 1851, and part for a number of years previously, than from either of the plots artificially manured during the same period. There was, in every case, rather more from Plot 5, which received mineral manure alone in 1852, and each year since; but mineral manure in each, with ammonia-salts, or nitrogenous organic matter, or both, in 7 out of the 8 preceding years. There was, further, in each case, more nitrogen in the drainage-water when, to the mineral manure, ammonia-salts = 41 lbs. of nitrogen was added; with one slight exception again more when 82 lbs. were employed; and more still with 123 lbs. nitrogen supplied.

That is to say, with each increased supply of nitrogen by manure, as ammonia-salts, there was an increased loss of nitrogen as nitric acid in the drainage-water.

It must be borne in mind that, in the experiments on wheat here referred to, the ammonia-salts were always sown broadcast in the autumn, and ploughed or harrowed in before sowing the seed; and it is seen that the amount of nitrogen as nitric acid in the drainage-water is much greater on the three occasions of winter collection, that is, soon after the manures were sown, and when there was no growth, than on either of the two occasions of spring collection, that is, after the washing out by the winter rains, and when active growth had set in.

The nitrate of soda is, however, always sown as a top-dressing about the middle of March. Accordingly, there was, in each case of winter collection, much less nitrogen as nitric acid in the drainage from the nitrated plot (9), than in that from Plot 7, which received the same amount of nitrogen as ammonia-salts applied in the autumn. On the other hand, in both cases of spring collection—that is, after the sowing of the nitrate—the amount of nitrogen as nitric acid was much greater in the drainage from the nitrated plot, than in that from the plot which had received the same amount of nitrogen as ammonia-salts in the autumn. In one case, indeed, April 21, 1868, the nitrate having been applied on March 18, the quantity of nitrogen as nitric acid in the drainage from the nitrated plot amounted to 5·83 parts per 100,000 parts of water. Assuming (which, however, was probably not the case) that an inch of rain passed as drainage of that strength, this would represent a loss of about 13 lbs. of nitrogen per acre! On this point it may be stated that for every inch of rain carrying with it into the drains, or below the reach of the roots, 1 part of nitrogen per 100,000 parts of water, there will be a loss of 2¼ (2·26) lbs. of nitrogen of manure per acre. If this fact be clearly fixed upon the mind, its great practical importance cannot fail to be recognised.

Since this Section was in type, we have been favoured by Professor Frankland with numerous results of analysis of drainage-water from the differently manured plots in the experimental field at Rothamsted, samples of which had, at his request, been supplied to him for investigation. He has also been good enough to give us permission to publish some of the results obtained relating to the amount of nitrogen in the waters in the form of nitrates and nitrites. Accordingly, we have, with his approval, selected for illustration those relating to the same plots as in the case of Dr. Voelcker's analyses, and those relating to six different periods of collection are taken.

When considered in detail—with due regard to the supply of manure, to the previous rainfall, to the period of collection, to

TABLE XLVI.—Composition of Drainage-water from Plots differently Manured; Broadbalk Field, Rothamsted; Wheat every Year, commencing 1844.

Nitrogen as Nitrates and Nitrites, per 100,000 parts of Water. Professor FRANKLAND'S Results.

DATES OF COLLECTION, &c.	MANURES PER ACRE, PER ANNUM.						
			Sulphates of Potass, Soda, and Magnesia, and Superphosphate of Lime.				
	14 Tons Farmyard Manure, every Year. Plot 2.	Without Manure, every Year. Plots 3, 4.	Without Nitrogen in Manure since 1851. Plot 5.	And 41 lbs. Nitrogen as Ammonia-salts. Plot 6.	And 82 lbs. Nitrogen as Ammonia-salts. Plot 7.	And 123 lbs. Nitrogen as Ammonia-salts. Plot 8.	And 82 lbs. Nitrogen as Nitrate Soda. Plot 9.
Jan. 5, 1872, moderate flow	2·592	1·312	1·418	2·777	4·744	7·841	2·311
May 18, 1872, moderate flow		0·031	0·071	0·051	0·059	0·094	1·647
June 11, 1872, small flow		0	0	0	0	(1)	(1)
Oct. 26, 1872, moderate flow	0·932	0·366	0·360	1·354	2·303	1·808	0·975
Jan. 19, 1873, moderate flow	0·084	0·057	0·157	0·454	1·294	1·522	(2)
Feb. 26, 1873, small flow	0·082	0·131	0·088	0·122	0·461	0·441	0·264
Means	0·922	0·316	0·349	0·793	1·477	1·951	1·039

(1) In these cases the drains did not run; and as there was little or no loss of nitrogen from those that did, it is assumed that there was little or none in these, and hence, for fair comparison, the means are—for Plots 3–4, 5, 6, 7, and 8, taken as for 6 experiments. For Plot 2, however, they are only taken for 4, and for Plot 9 for 5, experiments.

(2) On January 19, 1873, the drain from Plot 9 ran a little, but had ceased to do so when the samples were collected.

the growth of the crop, and to the rate of flow—these results of Dr. Frankland's not only strikingly confirm the conclusions drawn from those of Dr. Voelcker, but they afford additional points of interest. Thus, there is not only an obvious gradation in the amount of nitrogen, as nitrates and nitrites, comparing plot with plot, according to the amount of nitrogen supplied in the manure, but, dependent on the conditions above enumerated, there are both higher and lower amounts than in any of the cases investigated by Dr. Voelcker.

In the autumn of 1871 the farmyard-manure plot received its dressing on October 22nd, and the mineral manures and ammonia-salts were applied on October 18 and 22. During November, and the first half of December, there was much less than the usual amount of rain; about the 20th of December there was a fall of rather more than half an inch, and from that time to the end of the month there was more or less rain almost every day; giving, however, a total for the month of considerably less than the average. Still, the soil had gradually acquired a good deal of moisture; and, on December 30th, a few of the drains in the experimental wheat-field ran a little. There was a little rain registered on January 1, 2, and 3, 1872, more than one-quarter of an inch on January 4th, more than half an inch on January 5th, and again more than half an inch on January 6th. On January 4th a few of the drains ran, and on both the 5th and 6th the whole of them. The results given in the first line of the Table (XLVI.) relate to samples collected on January 5th, which was the first occasion on which all the drains ran since the application of the manures in October.

The drainage from the Plots 3–4, both of which have been entirely unmanured since 1851, and one for some years previously, shows the lowest proportion of nitrogen as nitrates; that from Plot 5, which had received mineral manure alone in 1852, and each year since, but mineral manure and ammonia-salts for several years previously, contained rather more; that from Plot 6, with ammonia-salts equal 41 lbs. nitrogen per acre per annum, much more; that from Plot 7, with ammonia-salts equal 82 lbs. nitrogen per acre per annum, again much more; and that from Plot 8, receiving 123 lbs. nitrogen per acre per annum, very much more still—in fact, more than in any other case examined by either Dr. Frankland or Dr. Voelcker, and an amount corresponding to a loss of 17¾ lbs. of nitrogen per acre, provided that an inch of rain passed away as drainage of that strength. The drainage from the nitrated plot, on the other hand, which had not received any nitrate since the previous spring, showed less loss of nitrogen than Plot 6, which receives only half the quantity of nitrogen annually, but in the form of ammonia-salts, which had been applied in the autumn.

During the rest of January (1872) some of the drains ran very frequently, and nearly all of them more than once; in March, again, many of them ran twice, and on May 18th there was a discharge from all excepting that from the dunged plot. In fact, in January there was a great excess of rain; in February a fair amount; in March considerably more than the average; in April nearly the average; and in May a considerable excess. Up to the middle of May, therefore, the soil had been subjected to an unusual washing out; whilst growth would then have advanced considerably, and the roots would have established command over the soluble matters within the soil. The result is, that the amount of nitrogen in the drainage at that date was extremely small in all the cases of autumn manuring by ammonia-salts; but it was very much greater where the nitrate had been applied on March 7th. It is true that the actual amount of nitrogen as nitrates and nitrites in a given quantity of the drainage from the nitrated plot was less in May, after the sowing of the manure in March, than it was in January, when no nitrate had been sown, and a crop had been grown since the application of the manure in the previous March; but in May the quantity in the drainage from the nitrated plot was very many times greater than in that from either of the plots which had been manured with ammonia-salts, whilst in January it was less.

After the collection on May 18th, there was about one-third of an inch of rain before the end of the month, bringing up the total to notably more than the average. In June, again, there was an excess of rain, more especially during the first third of the month; on June 9th a few of the drains ran, and on June 11th most of them, though only slowly. Samples of the drainage from eight of the plots were sent to Dr. Frankland; and although in three of them a very small amount of nitrogen as nitrates and nitrites was found, the Table shows that there was none whatever in that from either of the plots to which the results there given refer. This is a very interesting fact; and it is doubtless accounted for, in part by the previous washing out of the soil, and in part by the extent to which the growing crop would, by the middle of June, have availed itself of assimilable nitrogen within the soil.

It only remains to add, in reference to the season thus far referred to, that, after such considerable loss by drainage during the winter, the crops in the experimental wheat-field which had been manured with mineral manure and ammonia-salts, applied in the autumn, were considerably below the average obtained under corresponding conditions in other years, whilst the produce by mineral manure and nitrate of soda—the latter not applied until the spring—was considerably above the average.

From June 11th until October 25th none of the drains ran; but there was a flow from most of them on the 25th, 26th, and 27th of the latter month; and, as the Table shows, samples of the drainage of October 26th were collected and analysed. The dung had been put upon its plot on October 14th; the mineral manures and the ammonia-salts were sown on October 16th and 17th. There was more or less rain registered each day afterwards, until, on the 24th there was about one-third of an inch, on the 25th more than half an inch, and on the 26th nearly nine-tenths of an inch. These heavy rains had come on when the land was only partly ploughed, only one or two plots being finished, and some scarcely touched. At the time of the collection of the drainage, therefore (October 26th), scarcely two plots were in the same condition as to the working of the land, so that some irregularities in the relative composition of the waters would be expected. There was still, in the main, a gradation in the amount of nitrogen as nitrates in the drainage-water, according to the amount of ammonia-salts applied; but the quantities were, throughout, comparatively low for winter-drainage collected soon after the sowing of the manure. This was probably in part due to the soil not having been completely broken up, and the manures, therefore, not being thoroughly distributed, but partly also to washing out, or dilution, for many hours before the samples were collected.

Some of the drains ran, more or less, eight times during November, and most of them two or three times. In December, again, most ran six, and some seven times, completing a year of much more frequent running than any since the observation of them commenced in 1866.

On January 2, 4, and 5, 1873, the drains from all excepting the dunged plot, and on January 3rd, 10th, and 19th, from all, without exception, ran. On January 3rd there was a very full, but at each of the five other dates only a moderate, flow. On January 19th samples were collected from all the plots excepting No. 9, the flow from which had stopped when the collection was made. Since the collection on October 26, 1872, there had been about 5 inches more than the average fall of rain; some of the drains had run more than twenty, and most sixteen or seventeen, times; whilst, even since the beginning of the month, all but the dunged plot had previously run five times. Accordingly, after so much washing out of the soil, the amount of nitrogen as nitrates and nitrites was comparatively small for winter-drainage; but there was very obvious gradation in the amount according to the quantity of ammonia-salts which had been applied.

Between January 19th and February 26th there were frequent, but not heavy rains (or snow-falls), but at the latter date about two-thirds of an inch of melted snow and rain were registered, all the drains ran, and samples were collected and sent to Dr. Frankland. After such an unusual washing out of the soil since the sowing of the manures in October, the drainage of February 26th is seen to contain, for that period of the year, a very small amount of nitrogen as nitrates and nitrites. There is still something like gradation according to the amount of nitrogen supplied in the manure; and, as would be expected, there is less in the drainage from the nitrated plot than in that from Plot 7, which receives the same amount of nitrogen annually, but applied as ammonia-salts in the autumn.

In connection with the very unusually large amount of water passing from the land by drainage during the past winter, 1872–73, it is of much interest to remark that, whilst at the present time (June 1873) the plots in the experimental wheat-field which received their dressing of ammonia-salts in October, are looking very much worse than usual, in fact, extremely unpromising, others, which were top-dressed with ammonia-salts or nitrate of soda in March, show much greater luxuriance.

With regard to the dunged plot (2), it has been explained (p. 139), that, owing to the greatly increased porosity of the soil by the application of farmyard manure so many years in succession, the drains from it very seldom run. It happens, therefore, that they do so only when there is a very great excess of rain; and, when there is such excess, a surface-drain, which first crosses the furrows of all the other plots, then crossed that of the dung, and passed not many yards from the outfall of that plot, has generally been running, so that there has sometimes been doubt whether the drainage from the dunged plot were not more or less affected by the percolation of this surface-water. Other cross-surface drains have, however, from time to time, been cut, to obviate this as far as possible; and it is believed that, at any rate during the past winter, there has been no danger of such percolation. Moreover, the results relating to Plot 2, recorded in the Table, though so different at the four periods of collection, are so far consistent with each other that, in each case, the drainage-water contains somewhat less nitrogen as nitrates and nitrites than that collected at the corresponding date from Plot 6, which received only 41 lbs. of nitrogen per acre per annum, but in the form of ammonia-salts; whilst, as already stated (p. 139), the dung is estimated to supply nearly, if not quite, 200 lbs. of nitrogen per acre per annum. But there has been a great accumulation of the nitrogen supplied by manure in the soil of the dunged plot, especially near the surface, and very much more than in that of the plots manured with ammonia-salts or nitrate of soda. It is further worthy of remark, that there is a general consistency between these results relating to the drainage from the dunged plot, and those obtained by Dr. Voelcker; for, in one case examined by him, the amount of nitrogen as nitrates, &c., also ranged somewhat below that in the drainage from Plot 6, and in the other not much above it.

In regard to wheat, therefore, it has been experimentally established, that, even when a comparatively moderate amount of ammonia-salts was applied as manure, only about one-third of the nitrogen so supplied was recovered in the increase of the crop; that the unexhausted residue, if any, was but very slowly, and very partially recovered as increased yield in succeeding years; that, nevertheless, there was an accumulation within the soil itself, of some of the nitrogen not at first recovered in increase; but that there was a loss by drainage which increased almost in proportion to the amount of nitrogen supplied in the manure.

The question arises—whether the whole of the supplied nitrogen which is not recovered in the crop either remains in the soil, or is lost by drainage?

Owing to the difficulty of determining with certainty, either the total amount of nitrogen retained by the soil within the reach of the roots, the proportion of the total rain passing beyond their reach, or the average composition of the drainage, absolute proof on this point is not at command. The following illustration will nevertheless be useful.

Of the total nitrogen supplied to the wheat plot No. 7, during the 20 years, 1852–1871, it may be assumed that about 33 per cent. was recovered in the increase of crop, leaving 67 per cent. to be otherwise accounted for. The determinations of nitrogen made in the samples of soil collected in 1865 are obviously not strictly applicable to the present calculation; but from them it may perhaps be concluded that approximately one-third, or possibly more, of the nitrogen not recovered in the increase of crop, remains accumulated within the soil to the depth of the 27 inches examined. This would leave say 44 per cent. of the 82 lbs. of nitrogen annually applied as manure, or, in other words, an average of 36 lbs. of nitrogen, to be annually accounted for by drainage or otherwise. Now, there can be no doubt that by far the larger proportion, though not the whole, of the drainage takes place during the autumn and winter months; and taking the mean of Dr. Voelcker's three determinations of nitric-acid in the winter drainage from this plot, the amount of nitrogen so found in it is 2·16 parts for 100,000 of water. As 1 inch of rain is equal to a fall of 226,263 lbs. (about 101 tons) of water per acre, every inch passing as drainage beyond the reach of the roots, and containing 1 part of nitrogen per 100,000, would carry with it 2¼

(2·26) lbs. of nitrogen per acre; and 2·16 parts per 100,000 would represent a loss of nearly 5 (4·88) lbs. per acre for each inch of rain so passing. At this rate it would require little more than 7 (7·38) inches of rain to pass beyond the reach of the roots to account for the whole loss of nitrogen observed in the case of the wheat plot No. 7.

We have said that the actual amount of drainage is unknown; and since, in the case of the land in question, the subsoil of clay rests upon chalk at from 6 to 10 feet from the surface, and there is, therefore, natural drainage constantly going on, no gauging of the flow of the pipes, however exact, would indicate the total amount of water passing. Other experiments at Rothamsted have, however, proved, that from one-third to one-half of the annual rain may pass below 40 inches. Supposing only one-third of the total fall so to pass, an average of from 8 to 9 inches of rain would annually drain away, by far the greater proportion of which would go off during the autumn and winter months.

The quantity and composition of the drainage-water here supposed would obviously be sufficient to account for more than the whole of the loss of nitrogen from Plot 7 as above indicated. On the one hand, however, some allowance in the way of deduction must be made for the amount of nitrogen as nitrates and nitrites in the drainage, due to accumulations within the soil prior to the period included within the estimate, or to other normal annual sources; but whether, with the large annual supply of nitrogen by manure, and the much more active root development, in the case of Plot 7, the amount of nitrogen in the drainage-water from that plot, due to sources other than the annual direct supply of nitrogenous manure, would be as much as that indicated in the drainage from either plots 3, 4, or 5, may be a question. On the other hand, the proportion of the drainage to the rain-fall, in the case of the soil in question, would probably average more than one-third, which amount only is assumed in the above estimate.

Although the selection of samples sent to Dr. Frankland was very fortunate, so far as the illustration of the wide difference in the composition of the drainage from the same plot at different times is concerned, his results are, on that account, the less directly available as a means of forming a judgment of the probable *average* composition of the drainage throughout any particular season of the year. To this end it would be desirable to have had results relating to the period between January 5 and May 18, 1872; and again to that between October 26, 1872, and January 19, 1873. Still, taking Dr. Frankland's results as they stand, the mean proportion of nitrogen as nitrates and nitrites in the samples of drainage from Plot 7, collected on

January 5 and October 26, 1872, and on January 19 and February 26, 1873, is higher than that in the winter drainage from the same plot examined by Dr. Voelcker, and adopted in the illustrations above given.

It should be added that, even the drainage from the plots manured exclusively with mineral manure and ammonia-salts or nitrate of soda would appear, according to Dr. Frankland's analyses, to contain nitrogen as ammonia and organic nitrogen, in amount averaging about 4 or 5 per cent. as much as that found as nitrates and nitrites, and by so much, therefore, increasing the loss of combined nitrogen by drainage, beyond that indicated by the quantity of nitrates and nitrites alone. In the drainage from the dunged plot, however, the amount of ammonia and organic nitrogen is, both actually, and relatively to the quantity as nitrates and nitrites, much more than in that from the artificially manured plots.

From the foregoing considerations it seems extremely probable that the whole of the nitrogen applied to the wheat as ammonia-salts or nitrate of soda, was either recovered in the increase of the crop, accumulated within the soil, or lost by drainage.

As the experimental barley-field is not artificially drained, we are unable to illustrate the point in the same manner in regard to the barley as to the wheat crop. It has, however, been conclusively shown that, in the case of the barley, a greater amount of increase is obtained for a given quantity of nitrogen in manure than in that of the wheat; and that a larger proportion of the nitrogen supplied is recovered in the increase of produce within a given time. How are these facts to be explained?

From the facts adduced, it is clear that a material loss of nitrogen takes place by drainage in the winter, when ammonia-salts are applied in the autumn for the wheat crop; and since the manures for the barley are not sown until the spring, all loss of the freshly-supplied nitrogen by winter rains is avoided. Further, not only would there be comparatively little drainage after the spring sowing, but growth being at once established, the nitrogen, whether applied in the form of ammonia or of nitrate, would be rapidly taken up. The analyses of the drainage from the wheat-field show that the water collected during the spring contained, compared with that of the winter, very little nitrogen. This is probably partly accounted for by the previous washing out of the soil in the winter, but it is doubtless also in a great measure due to the action of the growing crop. It is only what would be expected, therefore, that a given quantity of ammonia-salts applied for barley in the spring, should yield a much better result than an equal amount applied for wheat in the autumn.

Even in the wheat experiments, nitrate of soda has always been applied in the spring; but as, unfortunately, the same quantities have not been applied for the two crops, no exact comparison can be drawn between the results they respectively yield. Still, the evidence undoubtedly indicates that more increase has been obtained for a given amount of nitrate when applied to barley than to wheat. In this case, therefore, loss by winter drainage cannot account for the comparatively defective result with the latter crop. Part of it is probably due to the fact that the quantity which has been applied for wheat (550 lbs. per acre) is a heavy spring dressing; and, owing to the great solubility of the nitrate, and the little power of retaining it which the soil possesses, there would be a greater loss by spring and summer drainage the greater the quantity applied. In confirmation of this view, Dr. Voelcker's analysis of the drainage from the nitrated plot after the manure had recently been sown, showed twice as much nitrogen as he found in any case of winter drainage from plots receiving the same amount of nitrogen as ammonia-salts. In many seasons too, the crop is too heavy and laid. For barley, on the other hand, only half the amount of nitrate is used; and, consequently, there will probably be not only less loss of manure by drainage, but less loss of crop by laying.

With regard to the supposition that there was probably a less proportional loss of nitrogen by drainage from the nitrate when applied for the barley than for the wheat, it should further be borne in mind, that although the manure is for both crops sown in the spring, yet it is in the one case on land in a close and consolidated condition, and in the other on soil rendered as light and open as possible by recent working, and hence offering a greater surface for absorption and retention of the manure. There is probably also a more active root-development in the upper layers of the soil in case of the barley than in that of the wheat.

Whether or not the above suppositions afford an adequate explanation of the difference of result with the nitrate when applied to both crops in the spring, the difference in the case of the ammonia-salts applied for the wheat in the autumn, and for the barley in the spring, is at any rate much more conclusively accounted for. But there is another circumstance in connection with the point that should not be overlooked.

The proportion of the nitrogen of the ammonia-salts which is recovered in the increase of produce being much greater in the case of the barley experiments than in those with wheat, there remains, of course, much less to be accounted for by accumulation in the soil, and by drainage. There is pretty certainly much less loss by drainage. And, so far as the few determinations of nitrogen that have yet been made in the soils of the barley plots enable us to judge, it would seem probable that there is less accumulation in the soil also, especially in the lower layers. If this be really so, the explanation is that, as the application of the ammonia-salts for the barley is made with the soil in a more porous condition, when there is less risk of saturation by water, therefore less risk of washing out, and when growth almost immediately succeeds, the wide distribution of the ammonia (or of the nitrate resulting from its oxidation) is materially checked; whilst the residue thus remaining near the surface will be the more easily available to the abundant surface rootlets of succeeding barley crops. In this there would obviously be an element in the explanation of the greater effect upon succeeding crops, of the nitrogen of manure not recovered in the immediate increase, when it was applied in the spring for barley than when in the autumn for wheat.

The long continued effect from previous applications of nitrate of soda must obviously be explained in a very different way. As already referred to, a given surface of soil has much less power to retain either nitrate of soda, or other nitrates, than ammonia. Consequently, the nitrogen of the nitrate distributes much more rapidly, and widely, through the soil and subsoil, and, so far, is more liable to loss by drainage. On the other hand it has been explained (p. 56) that the effect of the nitrate, or its products of decomposition, is to cause the disintegration of the clay subsoil, and so to increase its porosity, and, therefore, its surface for the absorption and retention both of moisture and of manurial matters, and also its permeability to the roots. Hence, although a given surface of the clay subsoil will retain much less nitrogen as nitric acid than as ammonia, the surface itself being much increased, the defective power of retention of a given surface will, in so far, be compensated. Accordingly, it has been seen that the barley crop was much more independent of drought on the nitrated plots than on those manured with a corresponding quantity of nitrogen as ammonia-salts; and not only so, for there would appear to be a retention of nitrates by the subsoil, beyond that which would be anticipated considering their solubility; a result which is most probably due to the same increase of disintegration, porosity, and surface, as is assumed to account for the increased retention of moisture in the first instance, and subsequent extended development of root, and yielding up of water to the plant.

At any rate, whatever may be the exact explanation in either case, the facts are undoubted—that there was a considerable effect on succeeding barley crops from previous applications of nitrogen, both as ammonia-salts and as nitrate of soda; and that much greater effects, due to the residue of the supplied nitrogen, were observed when ammonia-salts were applied for barley in the spring, than when for wheat in the autumn.

To the foregoing illustrations of the effects of the unexhausted residue from previously supplied nitrogen, must be added some evidence as to the effects on succeeding crops of previously supplied mineral manures, or ash-constituents. The experiments on barley do not furnish absolutely unexceptionable comparative evidence on the point; though there can be little doubt that the superphosphate and sulphate of potass applied in the first year, 1852, on Plots 1 N and 2 N, have materially increased the effects of the nitrate of soda afterwards annually applied up to the present time. The experiments on wheat do, however, afford very conclusive evidence on the subject, and as we are now able to give the results of eight more seasons than when writing on the question in 1864, we append the following Table (pp. 152–3) relating to that crop.

For the crop of 1844, both plots, 10*a* and 10*b*, received a mineral manure, consisting of silicate of potass and superphosphate of lime. Every year since, 10*a* has been manured with ammonia-salts alone. 10*b* has been manured exactly similarly in every year excepting the third, fifth, and seventh (1846, 1848, and 1850); in 1846 it was left unmanured; in 1848 it received, in addition to the ammonia-salts, a mineral manure containing salts of potass, soda, and magnesia, and superphosphate of lime; and in 1850 the same mineral manure without the ammonia-salts. That is to say, during the first six years of the twenty-seven, the application of ammonia-salts was twice omitted on 10*b*, but it twice received mineral manure when 10*a* did not.

The Table shows that during the 6 years, 1845–50, 10*b*, with less ammonia-salts, but more mineral manure, yielded, in the aggregate, $14\frac{5}{8}$ bushels less corn, and $11\frac{1}{2}$ cwts. less straw, or $2\frac{1}{2}$ bushels corn, and $1\frac{7}{8}$ cwt. straw, less per acre per annum than 10*a*. On the other hand, in almost every year since up to the present time, a period of 21 years since the last application of mineral manure, 10*b* has yielded more of both corn and straw than 10*a*; in all $69\frac{3}{8}$ bushels more corn, and $61\frac{7}{8}$ cwts. more straw, or an average annual excess of $3\frac{3}{8}$ bushels of corn, and $2\frac{7}{8}$ cwts. of straw.

It is obvious that the excess of produce on 10*b*, over that on 10*a*, during the last 21 years, may be partly due to the less exhaustion of the mineral constituents of the soil on 10*b* during the first 6 of the 27 years, owing to the less supply of ammonia-salts to it during that period. But, if we deduct the difference between the produce on the two plots during these 6 years, from the excess of produce on 10*b* during the last 21 years, we still have, during the latter period, an aggregate excess of $54\frac{3}{4}$ bushels of corn, and $50\frac{3}{8}$ cwts. of straw, or an average annual excess of $2\frac{5}{8}$ bushels of corn, and $2\frac{3}{8}$ cwts. of straw, on 10*b*,

Table XLVII.—Experiments on Wheat.

Effects on succeeding Crops, of the Unexhausted Residue from previous Applications of Mineral, or Ash-constituents.

Years.	Produce per Acre.								
	Total Corn in Bushels of 61 lbs.			Straw (and Chaff).			Total Produce (Corn and Straw).		
	Mineral Manure, 1844.			Mineral Manure, 1844.			Mineral Manure, 1844.		
	Plot 10*a*. Ammonia-salts, 1845 and each year since. 27 years, 1845–'71.	Plot 10*b*. Ammonia-salts, 1845 and each year since, excepting 1846 and '50; Unmanured 1846; Mineral Manure, 1848 and '50.	10*b* over (or under –) 10*a*.	Plot 10*a*. Ammonia-salts, 1845 and each year since. 27 years, 1845–'71.	Plot 10*b*. Ammonia-salts, 1845 and each year since, excepting 1846 and '50; Unmanured 1846; Mineral Manure, 1848 and '50.	10*b* over (or under –) 10*a*.	Plot 10*a*. Ammonia-salts, 1845 and each year since. 27 years, 1845–'71.	Plot 10*b*. Ammonia-salts, 1845 and each year since, excepting 1846 and '50; Unmanured 1846; Mineral Manure, 1848 and '50.	10*b* over (or under –) 10*a*.
	Bushels.	Bushels.	Bushels.	Cwts.	Cwts.	Cwts.	lbs.	lbs.	lbs.
1844	16½	16½	..	9⅞	9⅞	..	2,120	2,120	..
6 years, 1845–'50 Total ..	175⅞	161⅛	–14¾	158⅛	146⅝	–11½	28,436	26,263	–2,173
6 years, 1845–'50 Average	29¼	26⅞	– 2⅝	26⅜	24½	– 1⅞	4,739	4,377	– 362
1851	32⅛	31¾	– 0⅜	27⅜	27¼	– 0⅛	5,036	4,985	– 51
1852	21⅝	22	0⅜	24⅞	25⅛	0¼	4,107	4,162	55
1853	10½	14⅝	4⅛	18¼	24	5¾	2,691	3,578	887
1854	36¼	41½	5¼	32⅛	39⅞	7¾	5,808	7,003	1,195
1855	21	29½	8½	22⅜	29⅛	6¾	3,797	5,073	1,276

1856	24⅝	28¼	3⅝	25⅛	28¼	3⅛	4,323	4,895	572
1857	29¾	35¾	6	21⅜	25⅝	4¼	4,208	5,060	852
1858	23½	29	5½	19	23⅜	4⅜	3,569	4,390	821
1859	19¾	24½	4¾	24⅜	30½	6⅛	3,937	4,920	983
1860	14¾	17⅜	2⅝	19¾	21⅛	1⅜	3,118	3,420	302
1861	14	16⅞	2⅞	17¼	19⅜	2⅛	2,784	3,196	412
1862	23⅞	26⅛	2¼	23⅛	25⅜	2¼	4,050	4,443	393
1863	42⅜	46¾	4⅜	31⅛	36¼	5⅛	6,068	6,914	846
1864	34¼	39¼	5	25¼	29	3¾	4,925	5,642	717
1865	27	31¾	4¾	21¼	23⅞	2⅝	4,034	4,615	581
1866	27¾	30¼	2½	24⅞	27¼	2⅜	4,485	4,895	410
1867	18⅜	20¼	1⅞	18⅛	19⅛	1	3,146	3,375	229
1868	26⅜	30¼	3⅞	19⅜	21⅛	1¾	3,790	4,210	420
1869	19¾	19⅜	− 0⅜	20¼	19½	− 0¾	3,475	3,374	− 101
1870	23¼	24½	1¼	14½	15⅝	1⅛	3,047	3,244	197
1871	11	10¾	− 0¼	11⅛	12	0⅞	1,927	2,002	75
21 years, 1851–'71 { Total ..	502⅛	570⅜	68¼	460⅞	522¾	61⅞	82,325	93,396	11,071
21 years, 1851–'71 { Average	23⅞	27⅛	3¼	22	24⅞	2⅞	3,920	4,447	527

which amounts at least must be attributed to the residue of the mineral manures supplied now more than 20 years ago.

The wheat experiments afford other illustrations of the lasting effects of certain mineral substances applied as manures; but owing to the very unusual exhaustion of the mineral constituents of the soil by the application of ammonia-salts alone so many years in succession in the cases above cited, the point is sufficiently forcibly brought out to render it unnecessary to adduce further evidence of the same kind on the subject.

The evidence afforded by the analysis of the produce, of the soils, and of the drainage waters, is, however, perfectly consistent with that of the field results.

Thus, numerous analyses of the ash of the grain and the straw of the produce of the experimental wheat plots show that of Plot 10*a* to have become relatively deficient, more particularly in phosphoric acid, but to some extent in potass also, during the later years.

Again, Baron Liebig's son, Hermann von Liebig, who had asked to be provided with samples for investigation, has partially analysed the soils from some of the Rothamsted experimental wheat plots; and, so far as the important constituents potass and phosphoric acid are concerned, he finds the amount of these much greater, especially in the upper layers of the soil, the greater the supplies by manure.

Lastly, on this point, Dr. Voelcker's analyses of the drainage waters show, that very much less of potass passed off in that way than of either soda, lime, or magnesia; and also very much less of phosphoric acid than of sulphuric acid or of chlorine; in fact, there is comparatively little loss by drainage of either.

The facts brought out in this Section may be briefly summarised as follows:—

1. When either ammonia-salts, or nitrate of soda, or nitrogenous organic matter in the form of rape-cake, or farmyard manure, was applied for either wheat or barley, a considerable proportion of the nitrogen so supplied remained unrecovered in the increase of the crop for which the manure was employed; nor was the whole recovered in many succeeding crops.

2. When ammonia-salts were applied in the autumn for wheat, a much less proportion of their nitrogen was recovered in the increase of crop, than when they were applied in the spring for barley or for oats.

3. Analysis of the soils to the depth of 27 inches, showed that there was a considerable accumulation within that depth, of the nitrogen of manure which had not been recovered in the increase of the crop; but that a still larger amount remained to be otherwise accounted for.

4. Analysis of the drainage waters from the experimental wheat plots showed that they contained a large amount of nitrogen in the form of nitrates; that the quantity of nitrates in the drainage was the greater the greater the amount of ammonia-salts applied as manure; and that (after autumn sowing), the quantity was very much greater in the winter, than subsequently in the spring and summer.

5. The analysis of the drainage waters further showed—that the winter drainage, after sowing ammonia-salts in the autumn, may often contain from two to three parts (and sometimes much more) of nitrogen (as nitrates and nitrites) per 100,000 parts of water. Calculation showed that, for every one part of nitrogen per 100,000 parts of drainage, there will be a loss of 2¼ lbs. of nitrogen per acre for every inch of rain passing beyond the reach of the roots. In one case Dr. Frankland's analysis showed 7·841 parts of nitrogen per 100,000 parts of drainage, corresponding to a loss of 17¾ lbs. of nitrogen per acre, provided an inch of rain passed as drainage of that strength.

6. A given surface of soil possesses much less capacity of absorption for nitrate of soda, or its products of decomposition, than for the ammonia of ammonia-salts. Consequently, heavy rains soon after sowing would carry off in the drainage water more nitrogen from a dressing of nitrate of soda, than from a corresponding dressing of ammonia-salts. In one case, after a heavy dressing of nitrate of soda in the spring, Dr. Voelcker found the drainage-water to contain 5·83 parts of nitrogen per 100,000 of water, corresponding to a loss of 13 lbs. of nitrogen per acre, per inch of rain so passing.

7. Owing to the much less loss by drainage in the case of spring than of winter sowing, there was not only more increase in the immediate crop from a given amount of nitrogen applied in the spring for barley (or oats) than in the autumn for wheat, but there was also much more effect upon succeeding crops, from the at first unrecovered amount, in the case of the barley than in that of the wheat.

8. It is probable that the whole of the nitrogen supplied as manure in ammonia-salts, or nitrate of soda, is either recovered in the immediate increase of crop, retained in the soil in a very slowly available condition, or drained away and lost.

9. Owing to the slow decomposition of the nitrogenous organic matter of rape-cake and farmyard manure, their nitrogen is less rapidly available than that of ammonia-salts or nitrate of soda; but, so far as can be judged from the direct experiments on the point, it would appar to be, at the same time, less subject to loss by drainage.

10. Certain important mineral or ash-constituents of manures

—potass, and phosphoric acid, for example—are, at any rate in the case of the heavier soils, almost wholly retained by them within the range of the roots; and they are found to be very lasting in their effects upon succeeding crops, provided there be a sufficient available supply of nitrogen within the soil.

Section V.—Results obtained in other Fields, and under other Conditions as to Cropping, Manuring, &c.

Before attempting to give a general summary of the results of the experiments on the growth of barley for 20 years in succession on the same land, or to draw any general or practical conclusions from them, it will be well to call attention to some results obtained in other fields, and under different, and in some cases less artificial, conditions as to cropping, manuring, &c. By the aid of the comparisons thus afforded, some judgment may be formed as to whether any conclusions drawn from the results obtained under the unusual conditions of the experiments which have been detailed, may be trusted as a guide to the requirements of the crop when grown on other land, or in the ordinary course of farming.

Two sets of experiments will be noticed. In the first of these, barley was grown for 3 years in succession on a series of plots which had previously been differently manured, and grown 10 crops of turnips in succession. In the other case, barley has been grown in four-course rotation, without manure, and with different descriptions of manure.

1. *Three Years of Barley after Ten Years of Turnips—Barn Field.*

The results of these experiments were considered in some detail in our former paper on the Growth of Barley ('Journal of the Royal Agricultural Society of England,' vol. xviii., Part II., 1858), and they will therefore be referred to less fully in this place.

For the turnips, the area of from 7 to 8 acres was divided into numerous plots, differently manured; and the object in view in afterwards taking 3 unmanured barley-crops from the land was to test the actual and comparative condition for corn-growing, in which the different plots had been left, and, as far as possible, to equalize their condition (especially so far as the nitrogen which had been supplied was concerned), before commencing a new series of turnip experiments.

The turnips were grown in the 10 years 1843–1852 (Norfolk Whites 6 years, Swedes 4 years). In Table XLVIII. (p. 159) is given the produce of barley in 1853, 1854, and 1855, on plots manured for the turnips as under :—

1. A series of plots having various purely mineral manures during the last 8 of the 10 years of the turnips.

2. Plots having the same mineral manures as 1, during the last 8 years, and ammonia-salts (an average of 45 lbs. of nitrogen per acre per annum) during the first 6 of the last 8 years, namely 1845-1850 inclusive.

3. Plots having the same mineral manures during the last 8 years as 1 and 2, and, in addition, an average of nearly 17 cwts. rape-cake (= 90 lbs. nitrogen) per acre, per annum, during the first 6 of the last 8 years.

4. Plots having the same mineral manures as 1, 2, and 3, during the last 8 years, and both the ammonia-salts (=45 lbs. nitrogen), and the rape-cake (=90 lbs. nitrogen), per acre, per annum, during the first 6 of the last 8 years.

There is also given in the Table the produce of barley in 1854 and 1855, on—

5. A portion of the previously mineral-manured turnip-land, dressed for the barley-crop of 1854 with ammonia-salts, at the rate of 400 lbs. per acre (= 82 lbs. nitrogen); but without further manure in 1855.

6. Another portion of the previously mineral-manured turnip-land, dressed with nitrate of soda, at the rate of 550 lbs. per acre (= 82 lbs. of nitrogen), for the barley-crop of 1854, and of 112 lbs. (=17 lbs. of nitrogen), for the crop of 1855.

The average produce of turnips over the last 8 years (1845–1852) was :—

	1. With Mineral Manure, alone.		2. With Mineral Manure, and Ammonia-salts.		3. With Mineral Manure, and Rape-cake.		4. With Mineral Manure, Ammonia-salts, and Rape-cake.	
	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
Roots	7	9	10	$4\frac{3}{4}$	10	$19\frac{5}{8}$	12	$3\frac{7}{8}$
Leaves	1	$10\frac{5}{8}$	3	3	2	$13\frac{1}{4}$	4	$7\frac{3}{8}$
Total	8	$19\frac{5}{8}$	13	$7\frac{3}{4}$	13	$12\frac{7}{8}$	16	$11\frac{1}{4}$

Thus, with purely mineral manures the produce was but small; with mineral manure and ammonia-salts it was more; with mineral manure and rape-cake again rather more; and with mineral manure, ammonia-salts, and rape-cake, together, it was the heaviest, but still, on the average, only about $12\frac{1}{5}$ tons of roots, and $4\frac{2}{5}$ tons of leaves, per acre per annum. On some portions the mineral manures supplied more of all the mineral constituents than were removed in the turnip-crops, but on others they did not; yet, there was so little difference in the subsequent produce of barley on the different mineral-manured plots, that only the average of all is given in each case in the Table.

For comparison with the produce of barley after turnips, there is also given in the top line of each division of the Table XLVIII. (p. 159), that without manure in the same seasons (which were the second, third, and fourth of the 20), in the field in which the crop has now been grown for so many years in succession.

The figures show that, over the three years, there were obtained after the mineral-manured turnips, an average of only 20 bushels of barley grain, and not quite 12 cwts. of straw, per acre per annum; or not two-thirds as much as without manure after barley, clover, wheat, barley, and barley, in the same seasons, in the field in which the crop is now being grown continuously.

If, as has been maintained on high authority, the increased produce of corn which is obtained in rotation, is due to the accumulation, or elaboration, during the growth of other crops, of the mineral constituents required for the corn, it might surely be expected that, after a series of mineral-manured turnip-crops, for which, on some of the plots, more of every mineral constituent was supplied in the manure than was taken off in the produce, we should have full crops of barley. But what are the facts? We have after the mineral-manured turnips three perfectly insignificant barley-crops, and much less than when barley was grown after three immediately preceding corn-crops.

The question arises—in what constituent, or constituents, had the mineral-manured turnips so exhausted the soil as to bring it into a condition even far worse for the after growth of barley than when (after clover) three white straw crops had been grown in succession—namely, wheat without manure, barley with sulphate of ammonia, and barley without manure?

It is seen that where, besides the mineral manures, ammonia-salts (experiment 2), rape-cake (experiment 3), and ammonia-salts and rape-cake together (experiment 4), were applied annually during the first 6 of the last 8 years of turnips, there was more produce of barley, both corn and straw, than where the mineral manures had been applied alone; and there was more where rape-cake, or ammonia-salts and rape-cake together, were employed, than where the ammonia-salts without rape-cake were used. The rape-cake not only supplied about twice as much nitrogen per acre as the ammonia-salts, but the nitrogen it contained would exist in a condition both less rapidly available and less liable to loss by drainage. The results obtained after the mineral-manured turnips (experiment 1) exclude the supposition that the increase of produce, where ammonia-salts had also been

TABLE XLVIII.—Three Years of Barley after Ten Years of Turnips.

BARN-FIELD.

PARTICULARS OF MANURES, &c.	PRODUCE OF BARLEY PER ACRE.			
	1853.	1854.	1855.	Average 3 Years
Dressed Corn—Bushels.				
Hoos-Field—				
Barley, without manure, after 3 corn-crops	26	$35\frac{1}{8}$	$34\frac{1}{8}$	$31\frac{3}{8}$
Barn-Field—				
Barley, after 10 yrs. Turnips manured as under—				
1 **Mineral** manures (last 8 years)	$20\frac{1}{2}$	$19\frac{1}{2}$	20	20
2 **Mineral** manures (8 yrs.); Ammonia-salts (6 yrs.)	$23\frac{1}{8}$	$21\frac{1}{4}$	$21\frac{3}{4}$	22
3 **Mineral** manures (8 yrs.); Rape-cake (6 yrs.)	$28\frac{3}{4}$	$24\frac{5}{8}$	$23\frac{1}{8}$	$25\frac{3}{4}$
4 **Mineral** manures (8 yrs.); Ammonia-salts and Rape-cake (6 yrs.)	$29\frac{1}{8}$	$23\frac{3}{4}$	$23\frac{3}{4}$	$25\frac{5}{8}$
5 **Mineral** manures (8 yrs.); Ammonia-salts, for Barley, 1854 ..	$(20\frac{1}{2})$	$52\frac{3}{8}$	$26\frac{5}{8}$	$39\frac{1}{2}$
6 **Mineral** manures (8 yrs.); Nitrate soda, for Barley, '54 & '55	$(20\frac{1}{2})$	$54\frac{7}{8}$	$40\frac{3}{8}$	$47\frac{5}{8}$
Straw (and Chaff)—Cwts.				
Hoos-Field—				
Barley, without manure, after 3 corn-crops	$17\frac{1}{4}$	$22\frac{1}{8}$	$17\frac{7}{8}$	$19\frac{1}{4}$
Barn-field—				
Barley, after 10 yrs. Turnips manured as under—				
1 **Mineral** manures (last 8 years)	$12\frac{3}{4}$	$12\frac{1}{2}$	$10\frac{1}{8}$	$11\frac{3}{4}$
2 **Mineral** manures (8 yrs.); Ammonia-salts (6 yrs.)	$13\frac{3}{4}$	$13\frac{5}{8}$	$10\frac{1}{2}$	$12\frac{5}{8}$
3 **Mineral** manures (8 yrs.); Rape-cake (6 yrs.)	17	$15\frac{7}{8}$	$12\frac{5}{8}$	$15\frac{1}{8}$
4 **Mineral** manures (8 yrs.); Ammonia-salts and Rape-cake (6 yrs.)	$16\frac{3}{4}$	16	$11\frac{3}{8}$	$14\frac{3}{4}$
5 **Mineral** manures (8 yrs.); Ammonia-salts, for Barley, 1854 ..	$(12\frac{3}{4})$	$39\frac{1}{8}$	$12\frac{3}{4}$	$25\frac{7}{8}$
6 **Mineral** manures (8 yrs.); Nitrate soda, for Barley '54 & '55 ..	$(12\frac{3}{4})$	$42\frac{5}{8}$	22	$32\frac{3}{8}$
Total Produce (Corn and Straw)—lbs.				
Hoos-Field—				
Barley, without manure after 3 corn-crops	3467	4462	3923	3951
Barn-Field—				
Barley, after 10 yrs. Turnips manured as under—				
1 **Mineral** manures (last 8 years)	2618	2474	2206	2432
2 **Mineral** manures (8 yrs.); Ammonia-salts (6 yrs.)	2864	2691	2331	2629
3 **Mineral** manures (8 yrs.); Rape-cake (6 yrs.)	3558	3171	2712	3147
4 **Mineral** manures (8 yrs.); Ammonia-salts and Rape-cake (6 yrs.)	3546	3136	2555	3079
5 **Mineral** manures (8 yrs.); Ammonia-salts, for Barley, 1854 ..	(2618)	7377	2852	5114
6 **Mineral** manures (8 yrs.); Nitrate soda, for Barley, '54 & '55	(2618)	8005	4727	6366

used, was due to any action that they might have in increasing the available supply of mineral constituents within the soil, or that the effects of the residue of rape-cake were attributable to the mineral constituents it supplied. There can, indeed, be no doubt that, in all three experiments, the increased produce of barley was due to an increased supply of available nitrogen within the soil where it had been applied in the manures for the turnips. Still, in neither case is there as much produce of barley as without manure in the other (Hoos) field, where the barley was grown after several previous corn-crops.

But experiments 5 and 6 afford conclusive evidence that it was of available nitrogen for the barley that the soil had become so exhausted by the growth of 10 successive crops of turnips.

Thus, in the second year of barley, 1854, those portions of the mineral-manured turnip-plots which were left without further manure (experiment 1) gave 19½ bushels of corn, and 12½ cwts. of straw, per acre; whilst a portion to which ammonia-salts, at the rate of 400 lbs. per acre, were applied (experiment 5), gave 52⅜ bushels of corn, and 39⅛ cwts. of straw; and where 550 lbs. nitrate of soda, containing about the same quantity of nitrogen as the ammonia-salts, was applied (experiment 6), there were obtained 54⅞ bushels of corn, and 42⅝ cwts. of straw. In fact, by the simple addition of ammonia-salts or nitrate of soda, from 3 to 3½ times as much total produce (corn and straw together) was grown.

Though not shown in the Table, it may be mentioned as remarkable, that although the produce without manure was very different in the two fields, that obtained when a given amount of nitrogen in the form of ammonia-salts or nitrate of soda was applied was very nearly identical in the different fields. The conclusion is that, in both, the mineral constituents, though abundant, were unavailing in the absence of a sufficiency of available nitrogen, but that when this was superadded, the amount of growth and produce was dependent on the amount of its supply, and the characters of the season.

Lastly, in the third year of barley after turnips (1855), the Plot 5, which had received ammonia-salts in the previous year, gave about 6½ bushels more corn, and 2¼ cwts. more straw, than the exclusively mineral-manured plots; and Plot 6, which again received nitrate of soda, but only in small quantity (112 lbs. per acre), gave more than twice as much of both corn and straw as the purely mineral-manured plots.

There is still evidence of another kind, which may be cited as showing that it was of available nitrogen that the turnips had rendered the soil so deficient for the after-growth of barley. It may be assumed that, on the average, between 25 and 30 lbs. of nitrogen would be annually removed from the Rothamsted soil by wheat or barley grown year after year without nitrogenous manure. But it is estimated that from the mineral-manured turnip-plots there were, over the 10 years, more than 50 lbs. of nitrogen per acre per annum removed. As, however, on some of the plots small quantities of ammonia-salts or rape-cake were applied in the first two years of the ten of turnips, it is, perhaps, more to the purpose to take the average over the last 8 years of turnips only; and this would show about 45 lbs. of nitrogen removed per acre per annum. An immaterial proportion of this might be due to the small amounts of nitrogenous manures applied in the first two years. Still, it may be assumed that about 1½ time as much nitrogen was removed from the land for 8, if not for 10 years, in succession, as would have been taken in an equal number of crops of wheat or barley grown without nitrogenous manure. No wonder, then, that considerably less barley has been grown in 3 years after a series of mineral-manured turnip-crops, than was obtained in another field after a less number of corn-crops.

The results obtained in Barn-field afford a striking illustration of the dependence of the turnip-plant on a supply of available nitrogen within the soil, and of its comparatively great power of exhausting it. They are also perfectly consistent with those in Hoos-field, in showing that mineral manures will not yield fair crops of barley, unless there be, within the soil, a liberal supply of available nitrogen. The results obtained under such very different conditions in the two fields are, in fact, strikingly mutually confirmatory.

2. *Barley in Four-Course Rotation of—Turnips, Barley, Clover or Beans, and Wheat—Agdell-Field.*

These experiments, which are still in progress, were commenced in 1848, so that the crop of 1871 was the twenty-fourth, and completed the sixth course. The produce of barley obtained in the first three courses was given in the paper above referred to, but it is now given, though in less detail for each course, for the six completed courses.

The area of about 2½ acres was divided into three equal portions. One-third has been left entirely unmanured from the commencement; one-third has been manured with superphosphate of lime * alone, once every 4 years, that is for the turnip-crop

* Quantities per acre, as under—

	Bone-ash.	Sulphuric Acid. (Sp. gr. 1·7).
	lbs.	lbs.
1st Course	100	100
2nd Course	160	120
3rd, 4th, 5th, & 6th Courses ..	200	150

commencing each course; and one-third, also for the turnip-crop only, with a complex manure, consisting of superphosphate of lime, salts of potass, soda, and magnesia, sulphate and muriate of ammonia, and rape-cake.*

From half of each of the three plots the whole turnip-crop (roots and tops) was removed; on the other half the roots were consumed on the land by sheep, and the uneaten leaves spread and ploughed in. In the first course clover was grown as the third crop; but in the second, third, fourth, fifth, and sixth courses, instead of clover, half of each plot was sown with beans, and the other half left fallow.

It would be out of place here, to describe the results obtained in these experiments on rotation, any more than is essential to explain the conditions under which the barley was grown. The results which will be noticed relating to that crop are only those obtained on the portion of each of the three plots from which the turnips were entirely removed, and on which, in the later courses, beans (not fallow) replaced the clover. The facts of chief importance in relation to the other crops are as to the quantity of turnips removed from the land before the growth of the barley. The average produce of turnips per acre over the first five courses (the crop failing in the sixth) was—

	Without Manure.		With Superphosphate alone.		With Mixed Manure.	
	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
Roots	1	6¾	6	16½	12	2½
Leaves	0	10½	1	8	2	2½
Total	1	17¼	8	4½	14	5

Under each of the three conditions as to manuring, the produce of turnips was much less in the later than in the earlier courses. This was, probably, partly owing to the higher condition of the land, dependent on previous manuring and cropping, at the commencement of the first than of the subsequent courses; but it was partly due to the characters of the seasons. Indeed, in

* Quantities per acre as under—

	Bone-ash.	Sulphuric Acid.	Pearl-ash.	Sulphate Potass.	Sulphate Soda.	Sulphate Magnesia.	Sulphate Ammonia.	Muriate Ammonia.	Rape-cake.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1st Course	100	100	100	..	..	..	100	100	1000
2nd Course	160	120	..	300	100	100	100	100	2000
3rd, 4th, 5th, & 6th Courses	200	150	..	300	200	100	100	100	2000

1868, the first year of the sixth course, turnip-seed was sown twice, but entirely failed, owing to the dryness of the season; and the land was then ploughed up, and left fallow for the barley.

The result in regard to the turnips may be stated in general terms as follows:—

Without manure there was scarcely any produce of turnips at all; there was, therefore, no exhaustion of the land by the removal of the crop; and it was, practically speaking, left fallow for the barley.

With superphosphate of lime alone only small crops of turnips were grown, especially in the later courses; still, much more was removed from the land than without manure; and, as nothing was supplied besides what the superphosphate itself contained, the land was, so far as other constituents are concerned, left in a much more exhausted condition for the growth of the barley than without any manure whatever.

With the mixed manure fair crops of turnips were removed in the earlier, but less in the later courses; and (excepting in the first year) there would remain in the land a considerable residue from the manures applied, and hence it would be left in a higher condition for the barley than after either the unmanured or the superphosphated turnips.

The produce of barley, under each of the three conditions as to manuring for the turnips, in each of the six successive courses, and on the average of the six courses, is given in Table XLIX. (p. 164); and, for comparison, there is also given, in the top line of each division, the produce, without manure, in the same seasons, in the field in which barley is grown year after year on the same land.

It will not be necessary to go into any detail respecting the produce of the individual years any further than to notice the apparently anomalous results of the first year. The much higher produce of barley after the unmanured than after the mixed-manured turnips, may be partly owing to some irregularities in the condition of the land at the commencement; but it is, doubtless, chiefly due to the fact that there had been removed from the unmanured plot only about $3\frac{1}{4}$ tons of roots, and $2\frac{1}{4}$ tons of tops, and from the mixed-manured plot nearly 11 tons of roots, and more than $7\frac{1}{2}$ tons of tops; whilst, as the foot-note at p. 162 will show, the mixed manure was much less liberal for the first than for the subsequent courses. There was, in fact, not only very much more turnips removed from the manured than from the unmanured plot, but there would be much less residue of manurial constituents, if any, left for the barley of the first course, than for that of either of the subsequent courses.

Table XLIX.—Barley in Four-course Rotation of—
Turnips, Barley, Clover or Beans, and Wheat.

Particulars of Manures, &c.	Produce of Barley per Acre.						
	1849.	**1853.**	**1857.**	**1861.**	**1865.**	**1869.**	**Average.**
Dressed Corn—Bushels.							
Hoos-Field—							
Barley, unmanured, after 3 Corn crops		26	$30\frac{1}{2}$	$16\frac{1}{2}$	$19\frac{1}{2}$	15	**$21\frac{1}{2}$**
Agdell-Field—							
Barley, in Four-course Rotation—							
Unmanured, continuously	$44\frac{7}{8}$	$34\frac{3}{8}$	$48\frac{1}{2}$	$38\frac{5}{8}$	39	$24\frac{5}{8}$	**$38\frac{3}{8}$**
Superphosphate, for turnips only	$29\frac{7}{8}$	$28\frac{5}{8}$	$28\frac{1}{2}$	$30\frac{5}{8}$	$33\frac{1}{4}$	$28\frac{3}{4}$	**$29\frac{7}{8}$**
Mixed Manure, for turnips only	$28\frac{7}{8}$	$38\frac{1}{4}$	48	$60\frac{5}{8}$	$47\frac{1}{2}$	$42\frac{7}{8}$	**$44\frac{3}{8}$**
Straw (and Chaff)—Cwts.							
Hoos-Field—							
Barley, unmanured, after 3 Corn-crops		$17\frac{1}{4}$	$14\frac{1}{2}$	$10\frac{3}{8}$	$8\frac{3}{8}$	$10\frac{3}{8}$	**$12\frac{1}{8}$**
Agdell-Field—							
Barley, in Four-course Rotation—							
Unmanured, continuously	$26\frac{5}{8}$	$21\frac{3}{4}$	$23\frac{1}{4}$	$22\frac{1}{2}$	$19\frac{1}{4}$	$17\frac{3}{8}$	**$21\frac{3}{4}$**
Superphosphate, for turnips only	$18\frac{7}{8}$	$16\frac{3}{4}$	$13\frac{1}{8}$	$17\frac{7}{8}$	$14\frac{3}{8}$	$18\frac{1}{8}$	**$16\frac{1}{2}$**
Mixed Manure, for turnips only	$18\frac{5}{8}$	$23\frac{1}{4}$	$21\frac{3}{4}$	$35\frac{1}{8}$	$23\frac{1}{8}$	$29\frac{1}{2}$	**$25\frac{1}{4}$**
Total Produce (Corn and Straw)—lbs.							
Hoos-Field—							
Barley, unmanured, after 3 Corn-crops		3467	3295	2107	2042	2016	**2585**
Agdell-Field—							
Barley, in Four-course Rotation—							
Unmanured, continuously	5656	4465	5337	4718	4182	3358	**4619**
Superphosphate, for turnips only	3841	3560	3076	3775	3394	3686	**3555**
Mixed Manure, for turnips only	3794	4873	5168	7391	5148	5800	**5363**

It has already been shown that the produce of barley was much less after 10 turnip-crops—the last 8 with mineral manures only—than after 3 preceding corn crops; but, as the top line in each of the divisions of the Table (XLIX.) shows, the produce grown year after year on the same land without manure declined considerably in the later years. It is now seen that the quantity of barley grown in rotation without manure, is very considerably greater than that grown in succession without manure. The produce is, indeed, considerably higher when grown in rotation after unmanured, than after superphosphated turnips. This is accounted for by the fact already stated, namely, that as scarcely any turnips were removed from the unmanured plot, the land was practically left fallow for the barley; whilst, from the superphosphated plot, the quantity removed would considerably exhaust the land.* Again (omitting the first year), the produce after the removal of the full-manured and larger crops of turnips was uniformly, and on the average, very much higher than after the removed superphosphated turnips, and also generally, and on the average, higher than after the unmanured turnips. This larger produce of barley after the removal of the larger crops of turnips grown by the mixed manure, is doubtless due to the fact that there would still be a considerable residue of the manure left within the soil.

It has already been shown, both by the results of the growth of barley year after year on the same land, and by those of its growth after the removal of a series of mineral-manured turnip-crops, that a liberal supply of mineral constituents alone is insufficient to secure a fair crop of barley. In both sets of experiments it was also shown that the further addition of nitrogenous manure raised the produce to a maximum. It might safely be concluded, therefore, that the larger produce of barley after the full manured, than after the superphosphated or the unmanured turnips in rotation, was not attributable to any residue of mineral constituents alone which would be left after the removal of the highly manured roots; and that the larger produce after the unmanured than after the superphosphated turnips was not due to a less exhaustion or greater accumulation of available mineral constituents where the smaller crop of turnips was removed.

But other evidence is not wanting to confirm the conclusion that the higher produce of barley after the unmanured than after the superphosphated turnips in rotation, and the higher produce still after the full-manured than after the unmanured turnips, were each due, in great part, to an accumulation of available nitrogen within the soil for the barley. Thus, it is estimated that, from the superphosphated plot, which yielded the smallest produce of barley, the turnips would probably, on the average of the five seasons in which they grew, remove about 50 lbs. of nitrogen per acre, or more than would be supplied in 200 lbs. ammonia-salts. From the unmanured plot they would remove only from one-fourth to one-third as much; and much less than would be contained in the increased produce of a corn-crop that would result from the fallowing of the land; so that, presumably, there would remain a considerable available store for the barley. From the mixed-manured plot, again, though the turnip-crop of the first course most probably removed considerably more

* The larger produce of barley on the superphosphated than on the unmanured plot in 1869 is only apparently an exception; for, as has been stated, the turnips failed in 1868, and there was, therefore, nothing removed from either plot in that year.

nitrogen than was supplied in the manure, the average produce of the subsequent courses would appear, by calculation, to have removed much less than was supplied; and, as most of that which was supplied was in the form of rape-cake, there would doubtless be an effective residue left within the soil.

To sum up the results on the point:—As in other experiments, so also in these, in which barley was grown in rotation, and under three very different conditions as to manuring, the evidence is sufficiently conclusive, and, therefore, corroborative of that in the other cases, that an essential condition for the growth of a full crop of barley, whether in rotation, or under less usual conditions, is a liberal supply of available nitrogen within the soil.

SECTION VI.—SUMMARY AND GENERAL CONCLUSIONS, SHOWING THE PRACTICAL BEARINGS OF THE RESULTS.

In a former paper it was shown, that wheat had been successfully grown for twenty years in succession on the same land; that the produce without manure had, during that period, diminished comparatively little; and that that by farmyard manure, and by certain artificial manures, had increased considerably. The thirtieth wheat crop is now growing, and shows no deterioration, in either quantity or quality, where the proper manures, natural or artificial, have been supplied. The most prominent result was, and still is, that mineral manures alone increase the produce scarcely at all; that nitrogenous manures alone increase it very considerably; but that the largest crops are obtained when nitrogenous and mineral manures are applied together.

How far do the results now recorded in regard to *barley* accord with those which have been obtained with its botanical ally—wheat?

The results on the growth of barley, without manure, by farmyard manure, and by a great variety of artificial mixtures, each used for twenty years in succession on the same land, have been given in detail in the foregoing pages; and they have been compared with those obtained with wheat under corresponding conditions. They have been classified, and given in separate sections, and at the conclusion of the sections they have been more or less formally summarised. It remains to call attention here to the most prominent results of the inquiry as a whole, with as little reference to detail as may be consistent with clearness, referring the reader to the detailed discussion of individual points, and to the summaries, given at the conclusion of preceding sections, for any further illustration or confirmation that may be needed.

The twenty-second crop of barley in succession is now growing, in a field immediately adjoining that devoted to the experiments on wheat, and having a soil and subsoil of similar general characters, namely, "a somewhat heavy loam, with a subsoil of raw yellowish-red clay, but resting in its turn upon chalk, which provides good natural drainage." It is obvious that, in wet seasons, such a soil is not well suited for the growth of the crop after roots fed on the land by sheep, as is the custom of the locality; but, the results which have been recorded abundantly prove that, when grown under favourable conditions, large crops of barley, of good quality, may be obtained from such land.

Without manure, the average produce of barley, over twenty years, was 21 bushels of dressed corn, of $52\frac{1}{3}$ lbs. per bushel, and 12 cwts. of straw. The quantity fell off considerably, but the quality was considerably higher over the second than over the first ten years. Compared with wheat without manure, barley gave more corn, less straw, but nearly the same quantity of total produce; it, however, fell off more in produce of grain, and about equally in straw, over the later years.

By Farmyard manure, the average annual produce was more than 48 bushels of dressed corn, of $54\frac{1}{3}$ lbs. per bushel, and 28 cwts. of straw. The quantity of both grain and straw, and the quality of the grain, were considerably higher over the second than over the first ten years. As without manure, so with farmyard manure, barley, compared with wheat, yielded more corn, less straw, but much about the same quantity of total produce.

Mineral manures alone gave very poor crops; and the quantity of both corn and straw fell off considerably during the later years. With barley there was much more grain, rather less straw, but considerably more total produce than with wheat.

Nitrogenous manures alone gave much more barley than mineral manures alone; the produce declined much less in the later years; and, for twenty years in succession, fair, though not full, crops were obtained.

Nitrogenous and mineral manures together gave, for twenty years in succession on the same land, rather more of both corn and straw than farmyard manure, considerably more than the average barley crop of the country under rotation, and an average weight per bushel of between 53 and 54 lbs. With the same amount of nitrogen, and the same mineral manure, applied for twenty years, in the autumn for wheat, and in the spring for barley, the barley gave much more corn, more straw, and nearly one-third more total produce than the wheat.

Thus, then, with barley as with wheat, mineral manures alone failed to enable the plant to obtain sufficient nitrogen and carbon to yield even a fair crop. The greater effect of nitrogenous manures alone showed that the soil, in its practically corn-exhausted condition, was relatively richer in available mineral constituents than in available nitrogen. And the generally greater effect by nitrogenous and mineral manures together, than by farmyard manure—which contained not only very much more nitrogen, but a large amount of decomposing carbonaceous organic matter, and probably more of every mineral constituent than the crop—showed that the nitrogen of the farmyard manure was in a far less rapidly available condition, and that its supply of carbon was at any rate unessential.

It is hardly necessary to add, that the field results with barley, equally with those with wheat, are entirely inconsistent with the *mineral theory* so long in controversy, according to which—fertility was quite independent of the ammonia conveyed to the soil;—if only the necessary mineral constituents were supplied in sufficient quantity and in available form, our cultivated plants, graminaceous as well as leguminous, would derive sufficient ammonia from the atmosphere;—the presence of ammonia in our manures was immaterial; and—the entire future prospects of agriculture depended upon our being able to dispense with ammonia in our manures, therefore with animal manures.*

It is a very remarkable and very significant fact, that not only by farmyard manure, but also by artificial manures containing no carbon, an average of not far short of 50 bushels of barley-grain (or more if reckoned at only 52 lbs. per bushel), and nearly 30 cwts. of straw, or much more than the average crop of the country under rotation, should have been obtained by the growth of the crop year after year on the same land for twenty years in succession. Not only was such an average obtained over the twenty years, but there was even rather more corn, higher quality, only little less straw, and nearly identical total produce (corn and straw together), over the second compared with the first ten years, showing that, hitherto at least, there is practically no exhaustion by the continuous growth of such large crops under such conditions of soil and manuring.

It was with farmyard manure, however, the annual use of which has resulted in a very great accumulation within the soil, of nitrogen, of carbon, and probably of every mineral constituent also, that there has been the greatest increase of produce, and especially of corn, over the second as compared with the first ten years. On the other hand, without manure, with mineral manure alone, and with ammonia-salts alone—that is, with defective soil conditions—there was a considerable deficiency of both corn and straw over the second half of the period; the greater deficiency the more defective the manuring, and the greater the relative

* For further remarks on the present position of the mineral theory controversy, see pp. 6–7 and 14–16.

deficiency of nitrogen in the soil; for the falling off was considerably more marked with mineral manure alone, than with ammonia-salts alone.

It will be obvious that an average of 50 bushels of barley-grain, and 30 cwt. of straw, would not be maintained without great fluctuations from year to year, according to season. Indeed, in no two years of the twenty did one and the same manure yield precisely the same result both as to the quantity and the quality of its produce; nor were the seasons which were more or less favourable than the average for one description of manure equally favourable for other descriptions. Thus, comparing the least and the most productive seasons of the twenty, there were obtained (reckoning the total corn at 52 lbs. per bushel)—without manure 15½ and 37¾ bushels, or a difference of 22 bushels; with farmyard manure, 32 bushels and 60 bushels, or a difference of 28 bushels: lastly, with the two most productive artificial manures, there were obtained 30¾ and 36¼ bushels in the worst season, and 66 and 68 bushels in the best season, or a difference in favour of the good season of 35¼ and 31¾ bushels of grain. That is to say, with one and the same expenditure for manure, there was a difference in the quantity of the produce obtained in the two seasons, of from nearly 32 to over 35 bushels of corn, besides, in one case, nearly a ton of straw.

Not only, then, has the average produce over twenty years, by artificial, nitrogenous and mineral, manures, considerably exceeded the average barley crop of the country with rotation, but the difference between the produce by one and the same manure in the least and the most favourable seasons of the twenty was, itself, not much less than would represent the average barley crop of many localities.

As we have in substance frequently said, it is but a truism to assert that the growing plant must have within its reach a sufficiency of the mineral constituents of which it is to be built up. But the results obtained with barley, as well as those with wheat, have shown that, whilst it is essential that there be a liberal provision of mineral constituents within the soil, the amount of produce is more dependent on the supply by manure of available nitrogen than of any other constituent.

The practical question obviously arises—How much ammonia, or its equivalent of nitrogen in some other form, will, on the average, be required to yield a given amount of increase of wheat or barley grain, and its proportion of straw?

In our Report on the growth of wheat for twenty years in succession on the same land, it was shown that the quantity of increase obtained for a given amount of ammonia, or its equivalent of nitrogen, in manure, varied exceedingly according to the *amount applied*, to the *provision of mineral constituents within* *the soil*, and to the *seasons*. It was, however, stated, as a general practical conclusion, that, under the conditions the most comparable with those of ordinary practice, approximately 5 lbs. of ammonia, or its equivalent of nitrogen, were, on the average, required to yield 1 bushel increase of wheat, and its proportion of straw.

In like manner the experiments with barley have shown a very wide variation in the amount of ammonia required to yield a given quantity of increase, according to the *amount applied*, to the *provision of mineral constituents within the soil*, and to the *seasons*.

Thus, with superphosphate and 200 lbs. of ammonia-salts per acre per annum, for six years, 3·26 lbs., but with 400 lbs. 5·06 lbs. of ammonia were required to produce 1 bushel increase of barley-grain and its straw.

Again, with 200 lbs. of ammonia-salts for twenty years, there were required—on three plots where it was used with superphosphate 2·13, 2·41, and 2·10 lbs.; on one plot where it was used with salts of potash, soda, and magnesia, without superphosphate, 3·59 lbs.; and on one without any mineral manure at all, 3·68 lbs. of ammonia to yield 1 bushel of barley and its straw.

Lastly, with only 200 lbs. of ammonia-salts per acre per annum, and with superphosphate also applied, the difference in the amount of ammonia required to yield 1 bushel of increase was, according to *season*, from about 1½ lb. in the two most favourable, to 5·36 and 4·48 lbs. in the two least favourable seasons; whilst, with only the same moderate amount of ammonia-salts, but used without superphosphate, or without any mineral manure at all, the difference in result according to season was very much greater still.

Notwithstanding these very considerable, and very significant variations, it may be concluded, from a review of the whole of the data bearing on the point, that when an increase of barley is obtained by means of artificial manures, such as salts of ammonia, nitrate of soda, or Peruvian guano, an increase of 1 bushel of grain, and its straw, may, taking the average of seasons, be calculated upon for every 2 to 2¼ lbs. of ammonia (or its equivalent of nitrogen, 1·65 to 1·86 lbs.) supplied in the manure —provided the quantity applied be not excessive, and there be no deficiency of mineral constituents within the soil. When, however, rape-cake is used, rather more nitrogen in that form will be required to yield a given increase; but when the increase is obtained by sheep-folding, or by farmyard manure, very much less increase will be yielded in the year of the application, in proportion to the nitrogen contained in the manure.

Thus, whilst it was concluded that, on the average, about 5 lbs. of ammonia (or its equivalent of nitrogen) were required to yield 1 bushel of increase of wheat, and its proportion of straw, it is now assumed that only 2 to 2¼ lbs. of ammonia are required to produce 1 bushel increase of barley, and its straw. But whilst an average bushel of wheat may be reckoned to weigh 61 lbs., and its average proportion of straw 105 lbs., an average bushel of barley will weigh only 52 lbs., and its straw only 63 lbs. Hence, whilst it required 5 lbs. of ammonia in manure to yield 61 lbs. of wheat-grain, and 105 lbs. of straw = 166 lbs. of total produce, it only requires from 2 to 2¼ lbs. to yield 52 lbs. of barley-grain and 63 lbs. of straw = 115 lbs. of total produce. In other words, for the production of 100 lbs. increase of total produce of wheat, it required 3 lbs., and for the production of 100 lbs. increase of barley (containing a larger proportion of grain, but about the same amount of nitrogen) it required only from about 1¾ to 2 lbs. of ammonia in manure. That is to say, it required much more ammonia to yield a given amount of increase when applied in the autumn for wheat, than when in the spring for barley.

The following questions obviously suggest themselves:—

What proportion of the nitrogen supplied in manure will probably, on the average, be recovered in the increase of the crop for which it is applied?

Will the at first unrecovered amount have any marked effect on the immediately or early succeeding crops?

Will there be any residue retained by the soil and the subsoil, in such a state of combination, and distribution, as only to be yielded up, if ever, in the course of a long series of years?

Will there be any drained away and lost?

Lastly, will the answers arrived at on these points, in regard to wheat or to barley, be equally applicable to both crops?

With regard to the proportion of the nitrogen of artificial manures recovered in the increase of crop obtained by their use, in former papers it has been estimated, taking the average over a comparatively limited number of years, that about 40 per cent. was recovered in the increase of wheat, of barley, and of meadow-hay indifferently. But, by the aid of numerous new determinations of nitrogen in the produce of wheat for twenty years, of barley for twenty years, and of oats for three years, it now appears that, with the same mixed mineral manure in each case, and the same amount of ammonia-salts applied in the autumn for wheat, and in the spring for barley and for oats, rather less than one-third of the supplied nitrogen has been recovered in the increase of the wheat, but nearly one-half in that of the barley and the oats. When, however, there were applied, even for wheat, the same mineral manure and nitrate of soda, the latter sown in the spring, a not much less proportion of its nitrogen was recovered in the increase of the crop, than in the case of the ammonia-salts applied for barley in the spring, or of the ammonia-salts or nitrate of soda applied for oats in the spring.

Not only, then, did a given amount of nitrogen, supplied as ammonia-salts, yield much more increase of produce in the years of its application, when applied in the spring for barley than when in the autumn for wheat, but a larger proportion of it was recovered in the increase of the spring-sown crop.

The field experiments have further shown, that the at first unrecovered amount yielded scarcely any increase at all in succeeding years in the case of the wheat, but a considerable increase in that of the barley.

With both crops, however, there remained a considerable amount of the supplied nitrogen not recovered in either the at first, or the early succeeding, increase of produce; but there is obviously very much more to be otherwise accounted for in the case of the autumn-sown wheat than of the spring-sown barley.

With regard to retention by the soil, the results of the analysis of samples of the soils of many of the differently manured plots in the experimental wheat-field, taken in all down to a depth of 27 inches, showed that a considerable amount of the nitrogen which had been supplied in the manure, and not recovered in the increase of crop, was accumulated within the soil; but it was concluded that a larger proportion remained unaccounted for to the depth examined, than was there traceable, and that some of this had passed off by the drains, and some into the lower strata of the subsoil.

With regard to loss by drainage, numerous analyses, by Dr. Voelcker and Dr. Frankland, of the drainage waters from the Rothamsted experimental wheat-plots, confirmed the supposition that there had been a considerable loss of the nitrogen of the manures in that way. They showed that the quantity of nitrates in the drainage-water was the greater the greater the amount of ammonia-salts applied; and that, after autumn-sowing, the quantity was very much greater in the winter than subsequently in the spring and summer.

Calculation showed that, for every 1 part of combined nitrogen per 100,000 parts of drainage-water, there will be a loss of 2¼ lbs. of nitrogen per acre for every inch of rain passing beyond the reach of the roots as drainage of that strength. In one case of winter-drainage, after an application of 600 lbs. of ammonia-salts per acre in the autumn, Dr. Frankland's analysis showed 7·841 parts of nitrogen per 100,000 parts of water, corresponding to a loss of nearly 18 lbs. of nitrogen per acre, provided (which, however, is not probable) that an inch of rain had passed as drainage of that strength.

As would be expected, as the nitrate of soda was, even for wheat, always sown in the spring, the autumn and winter-drainage from the nitrated plot always contained much less nitrogen than that collected at the same date from the plots manured with ammonia-salts in the autumn. Owing, however, to the much less capacity of a given surface of soil for the absorption of nitrate of soda, or other nitrates arising from its decomposition, than of the ammonia of ammonia-salts, heavy rains, soon after sowing, would carry off more of the nitrogen from nitrate of soda than from a corresponding dressing of ammonia-salts. In one case Dr. Voelcker found, in the drainage collected from the nitrated plot soon after a dressing of 550 lbs. of nitrate per acre (= 400 lbs. ammonia-salts), applied in the spring, 5·83 parts of nitrogen per 100,000 parts of water, corresponding to a loss of about 13 lbs. of nitrogen per acre per inch of rain passing.

These facts, showing how great may be the loss of the nitrogen of manure by drainage, are obviously of the greatest practical importance, and demand very serious consideration.

Owing to the difficulty of determining with certainty, either the total amount of nitrogen retained by the soil within the reach of the roots, the proportion of the total rain which would pass beyond the reach of the roots, or the *average* composition of the drainage-water, absolute proof whether the whole of the supplied nitrogen which is not recovered in the crop is either retained by the soil, or lost by drainage, is not at command. Still, a consideration of such data as are available in reference to the points here indicated, points to the conclusion that the whole of the nitrogen which was applied as ammonia-salts or nitrate of soda to the wheat was either *recovered in the increase of crop, accumulated within the soil*, or *lost by drainage.*

As already said, as the proportion of the nitrogen of ammonia-salts which was recovered in the increase of produce was much greater in the experiments with barley than in those with wheat, there remained of course much less, in its case, to be accounted for by accumulation in the soil, and by drainage.

Only few determinations of nitrogen have as yet been made in the soils of the barley plots; but, so far as can be judged from the results obtained hitherto, it seems probable that there is less accumulation than in the case of the wheat, especially in the lower layers. It seems pretty certain, too, that there must be much less loss by drainage; but, as the experimental barley-field is not artificially drained, no direct evidence can be adduced on the point. It may be observed, however, that as the ammonia-salts are sown for the barley in the spring, when the soil is in a porous condition, when there is comparatively little risk of washing out, and when growth almost immediately succeeds, there will be a less immediate and wide distribution of the ammonia, or of the nitrate resulting from its oxidation, a larger proportion at once taken up by the growing crop, and, probably, a larger proportion fixed near the surface before the winter-rains, and remaining available there for succeeding crops.

Not only, then, do the results point to a satisfactory explanation of the loss of nitrogen which has been observed in the use of artificial nitrogenous manures, but also of the much greater loss when they are applied in the autumn for wheat, than when in the spring for barley or for oats. In confirmation of the explanation on the latter point, may be cited the facts that, not only was there on the average much more increase even of wheat, and much more nitrogen recovered in the increase, when a given amount of it was applied as nitrate of soda in the spring than when as ammonia-salts in the autumn, but the difference in favour of the spring-sown manure was especially marked after unusually wet autumns and winters.

There is another point to notice in connection with the action of nitrate of soda. A given surface of soil has much less power to retain either nitrate of soda, or other nitrates, than ammonia, and so far their nitrogen is, *cæteris paribus*, more liable to loss by drainage. Yet, when frequently used on the same land, such was the effect of the nitrate, or its products of decomposition, aided by increased development of root, in causing the disintegration, and so increasing the porosity and surface of the clay subsoil, that there would appear to have been not only a greater retention of moisture in an available form by the subsoil, rendering the growing crop more independent of drought, but also a greater retention of nitrates than would be anticipated considering their solubility, and, hence, a more lasting effect from previous applications than would otherwise be expected. On the other hand, where, as in the case of the experiments at Rothamsted, nitrate of soda has been used in large quantities so many years in succession, the surface soil has retained so much moisture as to be difficult to work after wet weather.

The results have shown, that a considerably less proportion of the nitrogen applied as rape-cake, than as either ammonia-salts or nitrate of soda, was recovered in the increase of crop within a given period of time, and again considerably less of that applied in farmyard manure than in rape-cake. Owing to the slow decomposition of the nitrogenous organic matter of these manures, their nitrogen is necessarily but slowly available. It would appear, however, to be, at the same time, less subject to loss by drainage; and analysis has shown that a large proportion of their nitrogen is retained by the soil, becoming but very gradually available for a considerable length of time. Indeed, analysis showed that where farmyard manure had been applied for wheat every year for twenty-five years in succession, the top 9 inches of soil contained nearly twice as high a percentage of nitrogen as the corresponding layers of any of the artificially manured plots, which, though they received much less nitrogen annually, as ammonia-salts or nitrate of soda, nevertheless yielded larger crops. Still, there is a large amount of the nitrogen of the dung not yet satisfactorily accounted for; but, whether there will be an ultimate loss of a greater or less proportion of that supplied, than when ammonia-salts or nitrate of soda is used, the data at present at command do not enable us to determine with certainty.

It is, then, established, that there is a great liability to loss by drainage of the nitrogen of manures, the available amount of which, more than of any other constituent, rules the amount of produce, under the existing conditions of British agriculture. The mineral constituents being, however, equally essential for growth, it is obviously important to have some direct experimental evidence showing whether or not they are also liable to such loss.

The field experiments with wheat have afforded conclusive evidence of the marked effect of potass and phosphoric acid supplied more than twenty years previously, when nitrogenous manures were afterwards applied to render them available; and, not only are the results of the analysis of the produce consistent with this, but the analysis of the soils has shown their accumulation, and that of the drainage-waters their comparatively little liability to loss in that way. Indeed, it may be concluded that, at any rate in the case of the heavier soils, these constituents, which, by the sale of corn and meat, would otherwise be the most likely to become relatively deficient, and which in that point of view are the most important to consider, are almost wholly retained within the reach of the roots.

Let it be granted—that, in one field at Rothamsted, wheat, and in another barley, have been grown for many years in succession, the same manure being applied to the same plot year after year; that, under these circumstances, it has been found that mineral manures alone have little or no effect, that nitrogenous manures alone have very much more, and that nitrogenous and mineral manures together will continue to yield as large crops as farmyard manure annually applied, and much larger than the average produce of the country under rotation. It may still be asked, whether conclusions drawn from results obtained under such unusual conditions may be trusted as any guide to the requirements of the crops when grown on any other land, or in the ordinary course of farming?

In our paper on the growth of wheat for twenty years in succession on the same land ('Journal of the Royal Agricultural Society of England,' vol. xxv., pp. 491–494), we adduced the results of direct experiments, made not only in another field at Rothamsted, but also in other localities, on soils of very different description, and in very different condition. The result in each case was, as in the experimental field, that there was but little increase by mineral manures alone, much more by ammonia-salts alone, and more still by ammonia-salts and mineral manure together. We further stated our conviction, founded on a very extensive acquaintance with the practical experience of farmers in the use of artificial manures in every district of Great Britain for many years, that, in 99 cases out of 100 in which wheat is grown in the ordinary course of agriculture with rotation, the supply of immediately available mineral constituents is in excess relatively to the immediately available supply of nitrogen.

In our former paper on the growth of barley, and again in Section V. of the present paper, evidence of a similar kind is adduced in regard to that crop. Two sets of experiments are quoted. In one, barley was grown for three years in succession on a series of plots which had previously been differently manured, and grown ten crops of turnips in succession. In the other, it was grown in four-course rotation, without manure, and with different descriptions of manure. The evidence of these other experiments is entirely confirmatory of the conclusion,—that mineral manures alone will not yield fair crops of barley, and that an essential condition for the growth of full crops, whether in rotation or under less usual conditions, is a liberal supply of *available nitrogen within the soil.*

Further, as in the case of wheat, so also in that of barley, the common experience of the country at large, in the use of artificial manures to that crop, is entirely confirmatory of the conclusions to which the results of the experiments on its growth year after year on the same land would lead.

It may here be remarked, that the greater liability to loss by drainage of the nitrogen, than of the more important mineral constituents of manure, is doubtless one element in the explanation of the fact of the prevailing excess of available mineral constituents, relatively to available nitrogen, in soils generally, under the ordinary course of agriculture in this country.

Those who have examined for themselves the evidence that has been adduced, and carefully considered the conclusions that have been drawn, in reference to the great number of points which this enquiry has opened up, will probably feel that they do not require any specific receipts to be laid down for their guidance, and that they will profit more by the direction which the study of the facts must give, to their own observation and reflections on what comes before them in the course of their daily experience. Indeed, under any circumstances, it must be left to the intelligence and the judgment of the individual farmer to decide upon the degree in which any special recommendations will be applicable to his own particular soil, and other circumstances.

Still, in bringing this long report to a conclusion, a few words should be offered by way of pointing out the more directly practical application of the results.

For twenty years in succession on the same land, an annual expenditure of less than 3*l.* per acre in artificial manures has yielded an average produce of 6 quarters of dressed barley, of good quality, and nearly 1½ ton of straw. Any practical farmer can estimate what would be the additional expense upon the crop, in the way of rent, cultivation, harvesting, bringing to market, &c.; and, having done so, the result will doubtless show a considerable profit.

The soil at Rothamsted is more suitable for wheat than it is for the growth of barley after roots, as is the common practice of the locality; but, the facts show that it will nevertheless grow large crops, of good quality, under favourable circumstances. Indeed, it may be laid down as a general rule, applicable to the country at large, that, on the heavier soils, full crops of barley, of good quality, may be grown with great certainty after a preceding corn crop, under the following conditions:—

First of all, it is essential that the land be got into good tilth. It should be ploughed up when dry, as soon as practicable after the removal of the preceding crop. In the spring it should be prepared for sowing, by ploughing or scuffling, as early in March as possible, if sufficiently dry.

The artificial manure employed should contain nitrogen, as ammonia or nitrate (or organic matter), and phosphates.

From 40 to 50 lbs. of ammonia (or its equivalent of nitrogen as nitrate) should be applied per acre. These quantities would be supplied in—

1½ to 2 cwts. of sulphate ammonia, or—

1¾ to 2¼ cwts. of nitrate of soda.

With either of these there should be employed—

2 to 3 cwts. mineral superphosphate of lime.

Of late years the composition of Peruvian guano has been so variable and uncertain, that it is quite impossible to estimate how much of it would be required to supply nitrogen equal to from 40 to 50 lbs. of ammonia. It is impossible, therefore, under such circumstances, to recommend it. If, however, the agents of the Peruvian Government manufacture their guano into a substance of uniform quality, and will guarantee to deliver it of a stated composition, it would be quite otherwise; and, as the guano itself contains phosphates, if the ammonia required were purchased in that form, superphosphate need not be also employed.

Rape-cake is also a good manure for barley. From 6 to 8 cwts. would supply about as much nitrogen as would be equal to from 40 to 50 lbs. of ammonia. But, a smaller proportion of the *of Barley,*

r on the same Land, without

PPENDIX-TABLE II. Dressed

description, or quantity, of Manure,

59.	1860.	1861.	1862.	1863.
shels.	Bushels.	Bushels.	Bushels.	Bushels.
13½	13¼	16¼	16½	22⅞
19⅝	15¾	25	21⅞	32⅜
15⅞	15¼	18⅞	19¾	27⅝
19¾	18¼	29⅜	25⅛	33
17¼	15⅝	22⅜	20¾	28⅞
15⅜	26⅝	30½	31⅜	42⅝
34½	43⅜	55	48⅝	61⅝
16⅞	28	32¾	35¼	48⅝
34⅝	43½	54⅝	47⅝	55⅜
25⅜	35⅜	43¼	40¾	52⅛
21½	25⅜	35	31½	49
35⅞	43¼	55¾	51	60½
20⅜	30¾	36⅞	36¼	54
35¾	46¼	55⅞	48¾	59½
28⅜	36⅜	45⅞	41⅞	55¾
8¾	31¾	56½	41	51⅞
1	36¾	56⅞	45	55
4⅛	35¼	51⅛	36	53⅛
5	40¾	53⅝	45½	54½
7¼	36⅛	54½	41⅞	53⅝
4⅞	27⅜	38¼	35½	51½
6½	29¾	41⅝	38⅜	53⅞
9½	10⅝	27⅝	23⅝	28⅛
6½	10⅛	28⅝	17⅜	29½
3⅛	39	49⅜	46⅝	51½
7⅛	12¼	16⅝	18½	27¼
4¾	12⅛	17⅞	19	28⅝
0	41⅝	54⅜	49¾	59½

f 9 years (1853–'61), last 10 years,
(4) Averages of 9 years (1853–'61),

MANURE, and with different descriptions of MANURE. Hoos Field, Rothamsted.

Corn per Acre—Bushels.

at the period indicated, for particulars of which see *Appendix-Table I.*, and sides-notes thereto, p. 179.]

HARVESTS.								AVERAGE ANNUAL.			PLOTS.
1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	First 10 Years, 1852–'61	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852-'71.	
Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.	
24	18	15⅞	17⅛	15⅝	15⅛	13½	16¾	22⅜	17½	20	1 O.
30¼	22½	22⅜	24⅝	18½	18¼	18	23⅛	27⅞	23¼	25½	2 O.
26⅛	22	19⅛	17	14¼	18¾	16¾	19⅝	24¾	20⅛	22⅜	3 O.
33¼	24⅜	24	20⅞	17⅝	22¼	18½	25	30½	24⅜	27½	4 O.
28⅜	21¾	20⅜	19⅞	16½	18⅝	16¾	21⅛	26⅜	21¼	23⅞	Means
38⅞	29⅞	27⅛	30⅝	20⅜	27⅞	27¾	36⅜	33⅝	31¼	32½	1 A.
58½	48⅜	50½	44	37⅝	48	41½	45⅛	45⅝	48⅜	47	2 A.
43⅞	33¼	27½	33	25	34¾	30⅞	38⅛	35	35	35	3 A.
55⅝	46½	47	43⅞	34⅝	49¼	38	46½	46⅛	46⅜	46¼	4 A.
49⅛	39½	38⅛	37⅞	29⅜	39⅞	34½	41½	40⅛	40¼	40¼	Means
41¾	33¾	29⅛	29¾	27	32⅛	29¼	39⅛	39¾	34¼	37	1 AA.
56⅞	47½	50⅞	44¼	44	48¼	46¼	46½	48⅞	49⅝	49¼	2 AA.
44⅝	34⅛	29¾	32⅞	27½	33⅞	32⅜	36⅛	38⅝	36⅛	37⅜	3 AA.
56⅜	48⅞	50⅞	45	45⅜	49⅞	44½	46	49⅞	49½	49¾	4 AA.
49⅞	41⅛	40⅛	38	36	41	38⅛	42	44¼	42⅜	43⅜	Means
44⅛	34⅞	37⅞	32¼	29⅜	34¾	35	48⅛	(1) 37¼	36⅞	37 (1)	1 AAS.
54⅞	47¼	51⅛	44	44⅞	49⅞	44¾	49½	49¼	47¼	48¼	2 AAS.
50	41	41⅞	39½	36⅜	40½	42¾	48⅜	43⅛	42	42⅝	3 AAS.
59⅛	50½	50¾	45¼	46⅝	51¾	47¼	48⅞	51⅜	48⅝	50	4 AAS.
52	43⅜	45⅜	40¼	39⅜	44¼	42½	48¾	45¼	43¾	44½	Means
48⅛	45	45⅞	38⅝	37	42½	41¾	44	47	43⅝	45¼	1 C.
51¾	46⅛	47½	45½	35¼	48¼	41¾	41¾	47¾	45¾	46¾	2 C.
49⅜	48¾	43⅞	38⅞	35⅛	43⅝	38½	45⅜	44	43¼	43⅝	3 C.
53	48⅛	48⅝	42⅝	36¼	52⅛	43¾	47½	47⅜	47¼	47⅜	4 C.
50½	47	46½	41⅜	35⅞	46⅝	41½	44⅝	46½	45	45¾	Means
40¾	37	34⅜	33	25½	35¼	34¾	43⅛	(2) 37⅝	37⅛	37⅜ (2)	1 N.
46¼	39⅞	41	36⅜	25⅜	38⅝	40¼	45⅜	42⅜	40½	41⅜	2 N.
25⅞	19¾	19	20½	14¾	16⅝	16⅛	22⅛	(3)(22⅝	20⅝	21½)(3)	M.
26½	23	22½	19½	15	23⅜	14½	20	(4)(24⅝	21⅛	22¾)(4)	5 O.
50¾	48¼	43⅞	34⅞	36⅛	49⅞	41¾	44¼	43⅜	44¾	44⅛	5 A.
25⅛	21	16⅛	16⅜	15¼	14⅞	15¼	18¾	25	18⅞	22	1 } 6
25⅛	19¼	17¼	19¾	15⅞	15⅜	15⅛	24¼	23⅞	20	21⅞	2 } 6
62	52¾	53⅛	45⅝	43⅝	46⅞	47½	54¼	45	51½	48¼	7

and total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.
last 10 years, and total 19 years.

EXPERIMENTS on the GROWTH of BARLEY year after year on the same LAND, without

APPENDIX-TABLE III. Weight

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure,

PLOTS.	HARVESTS.											
	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 O.	52·1	51·4	53·6	52·4	49·1	52·0	53·0	49·0	50·8	52·3	50·3	53·6
2 O.	52·6	52·6	54·0	52·5	46·5	52·8	54·0	52·0	50·5	53·3	52·0	54·2
3 O.	52·5	51·9	53·6	52·9	48·5	52·5	53·5	49·5	50·3	52·8	51·8	54·5
4 O.	51·5	52·1	54·0	53·1	47·0	53·7	54·0	52·5	51·3	54·0	52·0	54·8
Means	52·2	52·0	53·8	52·7	47·8	52·8	53·6	50·8	50·7	53·1	51·5	54·3
1 A.	50·7	52·4	53·6	51·8	48·5	51·9	53·0	47·5	50·8	51·5	49·4	53·6
2 A.	50·5	52·5	54·3	51·3	46·3	54·3	53·8	51·0	51·0	53·5	53·5	55·3
3 A.	50·9	52·6	54·0	52·2	49·1	52·1	54·0	47·5	50·8	51·5	50·5	54·3
4 A.	51·4	53·1	54·3	52·0	46·4	54·8	54·0	51·0	51·1	54·0	54·0	56·5
Means	50·9	52·7	54·1	51·8	47·6	53·3	53·7	49·3	50·9	52·6	51·9	54·9
1 AA.	49·1	51·3	52·8	50·6	48·3	52·0	53·5	47·5	50·7	51·8	50·0	53·9
2 AA.	49·5	51·7	52·4	50·1	46·1	53·5	53·3	50·7	51·3	53·5	54·4	55·7
3 AA.	50·6	51·3	53·1	50·2	47·3	52·1	53·9	47·5	50·4	51·5	51·5	54·5
4 AA.	50·6	51·4	52·1	48·9	45·4	53·9	53·5	50·5	51·0	53·5	54·0	56·4
Means	50·0	51·4	52·6	50·0	46·8	52·9	53·6	49·1	50·9	52·6	52·5	55·1
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	51·7	51·3	52·9	50·5	46·1	53·2	53·5	52·0	52·0	54·0	54·5	56·3
2 C.	51·8	51·6	52·8	50·0	47·3	53·8	52·8	51·5	51·5	54·1	55·3	56·4
3 C.	51·3	51·5	52·6	50·6	46·6	54·1	53·5	51·7	51·8	53·5	53·5	56·8
4 C.	51·4	50·4	52·8	49·5	46·3	54·1	53·1	51·0	51·1	54·3	54·0	56·7
Means	51·6	51·2	52·8	50·2	46·6	53·8	53·2	51·6	51·6	54·0	54·3	56·6
N.	(51·7)	51·3	53·3	52·0	50·0	52·9	53·5	48·0	51·0	52·0	51·5	53·4
2 N.		49·7	53·1	50·1	48·4	53·0	54·0	48·5	51·1	51·8	51·3	53·9
M.				52·6	49·3	52·6	53·6	49·5	51·0	53·8	52·8	53 8
6 O	(51·0)	51·8	53·1	52·6	47·5	53·4	54·0	51·0	51·0	53·3	51·5	54·1
5 A	51·0	52·3	53·8	51·5	46·6	54 5	54·0	51·0	51·2	53·0	52·0	55·6
5 {1	52·0	50·3	52·8	52·5	50·0	52·3	53·1	48·5	51·3	52·0	51·8	54·0
5 {2	53·0	50·9	53·6	52·6	50·0	52·3	53 1	47·5	51·0	52·0	52·0	54·1
	52·8	51·6	53·9	52·9	47·1	54·2	54·5	52·5	52·1	54·8	54·8	57·2

(1) Averages of 4 years, 4 years, and 8 years.

(2) Averages of 9 years (1853–'61), last 10 years,

(4) Averages of 9 years (1853–'61),

Manure, and with different descriptions of Manure. Hoos Field, Rothamsted.

per Bushel of Dressed Corn—lbs.

at the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.]

HARVESTS.								Average Annual.			
1864.	**1865**	**1866.**	**1867.**	**1868.**	**1869.**	**1870.**	**1871.**	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	PLOTS.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
55·7	53·9	51·1	51·8	54·3	52·4	52·9	55·0	51·6	53·1	52·3	1 O.
56·8	53·8	53·2	53·9	55·8	54·3	53·6	56·0	52·0	54·4	53·2	2 O.
56·9	54·5	52·3	52·9	55·7	54·7	54·3	55·4	51·8	54·3	53·0	3 O.
57·3	54·0	52·7	53·6	55·3	54·6	55·6	55·6	52·3	54·6	53·4	4 O
56·7	54·1	52·3	53·1	55·3	54·0	54·1	55·5	52·0	54·1	53·0	Means
55·4	53·8	50·9	51·3	53·3	52·4	54·6	55·6	51·2	53·0	52·1	1 A.
57·0	52·7	54·4	54·1	54·6	57·0	57·2	55·0	51·8	55·1	53·5	2 A.
56·4	54·7	52·1	51·9	54·8	54·6	55·4	56·1	51·5	54·1	52·8	3 A.
57·6	53·5	54·7	54·3	55·6	57·4	57·1	56·5	52·2	55·7	54·0	4 A.
56·6	53·7	53·0	52·9	54·6	55·4	56·1	55·8	51·6	54·5	53·1	Means
55·5	53·5	50·9	52·4	53·7	53·1	54·5	54·1	50·8	53·2	52·0	1 AA.
57·2	52·3	55·0	54·1	55·6	57·2	56·9	55·9	51·2	55·4	53·3	2 AA.
56·5	54·8	51·4	51·9	55·1	53·7	54·6	54·3	50·8	53·8	52·3	3 AA.
57·6	53·3	55·4	54·6	56·0	57·1	57·1	56·3	51·1	55·8	53·4	4 AA.
56·7	53·5	53·2	53·3	55·1	55·3	55·8	55·2	51·0	54·6	52·8	Means
56·1	54·2	51·8	53·5	54·2	54·8	55·0	54·6	(1) 53·9	54·6	54·3 (1)	1 AAS.
57·2	52·4	55·6	55·1	56·2	57·4	57·4	55·6	55·1	56·7	55·9	2 AAS.
57·2	54·8	52·5	53·0	55·5	56·6	55·9	53·8	54·4	55·5	55·0	3 AAS.
57·0	53·1	55·3	54·1	56·2	57·8	57·8	55·4	54·9	56·8	55·8	4 AAS.
56·9	53·6	53·8	53·9	55·5	56·7	56·5	54·9	54·6	55·9	55·2	Means
57·1	53·8	55·1	54·4	56·2	56·7	57·5	56·3	51·7	55·8	53·8	1 C.
57·0	53·3	55·7	55·0	56·1	57·1	57·8	56·4	51·7	56·0	53·9	2 C.
57·3	53·3	55·3	54·7	55·8	57·1	57·6	56·3	51·7	55·8	53·7	3 C.
57·2	53·5	55·6	54·8	55·4	57·4	58·0	56·4	51·4	55·9	53·6	4 C.
57·1	53·5	55·4	54·7	55·9	57·1	57·7	56·4	51·6	55·9	53·8	Means
56·0	54·1	52·0	52·9	52·8	54·3	55·6	54·6	(2) 51·6	53·7	52·7 (2)	1 N.
56·5	53·8	52·8	52·7	55·5	54·8	55·8	54·6	51·1	54·2	52·7	2 N.
56·3	54·4	52·9	53·9	54·0	54·0	55·3	55·0	(3)(51·8	54·2	53·2)(3)	M.
57·6	54·5	53·4	54·0	56·4	55·6	55·9	55·1	(4)(52·0	54·8	53·4)(4)	5 O.
57·5	54·1	54·8	55·2	57·5	57·5	57·3	55·5	51·9	55·7	53·8	5 A.
56·0	53·9	51·3	52·0	53·5	52·8	54·0	55·4	51·5	53·5	52·5	1 } 6
55·8	53·9	51·8	52·5	53·8	52·9	54·6	54·9	51·6	53·6	52·6	2 } 6
57·4	54·4	54·9	54·8	57·1	56·4	57·1	56·6	52·6	56·0	54·3	7

and total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.
last 10 years, and total 19 years.

Experiments on the Growth of Barley year after year on the same Land, without

APPENDIX-TABLE IV. Offal

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure,

PLOTS	HARVESTS.											
	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 O.	164	225	84	144	131	93	86	110	78	88	64	49
2 O.	100	101	101	69	58	106	103	159	84	78	114	58
3 O.	183	151	64	76	129	61	96	85	78	88	73	54
4 O.	136	160	105	94	88	53	108	160	74	58	117	57
Means	146	159	89	96	102	78	98	129	78	78	92	55
1 A.	218	253	201	138	219	113	98	184	150	170	269	116
2 A.	260	244	150	184	121	88	114	274	159	130	191	99
3 A.	252	336	197	177	180	91	96	175	115	109	269	108
4 A.	273	274	138	142	125	70	117	253	150	110	150	81
Means	251	277	172	160	161	91	106	222	143	130	220	101
1 AA.	299	303	326	204	310	135	88	215	109	173	296	110
2 AA.	315	251	329	181	233	133	134	320	118	190	133	143
3 AA.	318	236	334	212	290	108	118	265	122	138	364	95
4 AA.	246	301	273·	150	176	183	143	285	141	179	191	66
Means	294	273	316	187	252	140	121	271	123	170	246	103
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	170	268	178	219	173	135	103	225	120	154	154	85
2 C.	164	376	238	195	161	169	148	171	156	150	128	109
3 C.	190	296	248	183	189	156	105	236	115	204	190	71
4 C.	144	277	227	222	205	168	125	350	153	204	174	66
Means	167	304	223	205	182	157	120	246	136	178	161	83
1 N.	(94)	283	109	128	245	99	119	205	146	225	245	120
2 N.		228	286	224	193	151	110	235	179	190	216	114
M.				36	94	90	84	85	75	78	198	46
5 O.	(173)	68	113	50	96	101	71	110	73	73	193	41
5 A.	173	210	170	126	151	68	154	168	193	188	210	81
6 {1	120	200	144	116	152	72	84	121	88	73	75	51
6 {2	118	161	119	73	125	105	81	127	95	67	194	65
7	101	269	86	109	141	134	121	260	147	190	208	66

(1) Averages of 4 years, 4 years, and 8 years.

(2) Averages of 9 years (1853–'61), last 10 years,

(4) Averages of 9 years (1853–'61),

Manure, and with different descriptions of Manure. Hoos Field, Rothamsted.

Corn per Acre—lbs.

at the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.]

Harvests.								Average Annual.			
1864.	**1865.**	**1866.**	**1867.**	**1868.**	**1869.**	**1870.**	**1871.**	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	Plots.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
42	47	41	90	21	44	31	48	120	48	84	1 O.
69	38	21	53	29	89	18	33	96	52	74	2 O.
43	38	38	64	27	70	18	35	101	46	74	3 O.
41	28	55	60	25	69	26	48	104	53	78	4 O.
49	38	39	67	25	68	23	41	105	50	78	Means
99	58	94	115	49	139	23	105	174	107	141	1 A.
63	84	64	76	38	113	26	189	172	94	133	2 A.
83	51	106	94	34	95	24	89	173	95	134	3 A.
110	60	63	71	50	21	27	146	165	78	122	4 A.
89	63	82	89	43	92	25	132	171	94	133	Means
110	64	148	110	46	64	33	133	216	111	164	1 AA.
50	113	111	69	46	89	24	168	220	95	158	2 AA.
76	48	103	106	59	111	36	133	214	113	164	3 AA.
46	76	133	119	43	78	30	90	208	87	148	4 AA.
71	75	124	101	48	86	31	131	215	102.	159	Means
94	55	88	85	49	121	33	94	[1] 81	74	77 [1]	1 AAS
53	86	96	66	64	60	23	153	75	75	75	2 AAS.
70	50	141	79	39	136	29	130	85	84	85	3 AAS.
93	70	80	93	46	125	26	175	84	93	89	4 AAS.
77	65	101	81	50	111	28	138	81	82	82	Means
78	83	104	109	43	69	25	78	175	83	129	1 C.
92	44	89	89	64	111	24	88	193	84	138	2 C.
90	66	94	91	39	91	37	141	192	91	142	3 C.
123	69	128	72	42	67	28	124	208	89	149	4 C.
96	66	104	90	47	85	28	108	192	87	139	Means
74	98	124	119	61	150	33	99	[2] 173	112	141 [2]	1 N.
95	84	104	88	35	98	33	171	199	104	149	2 N.
58	69	44	56	26	61	25	58	[3] 77	64	69 [3]	M.
78	35	48	56	20	75	23	41	[4] 84	61	72 [4]	5 O.
91	94	53	74	33	63	30	144	160	87	124	5 A.
51	45	72	103	27	71	26	50	117	57	87	1 } 6
54	47	51	83	21	57	23	41	107	64	85	2 }
117	56	148	111	48	160	26	171	156	105	130	7

and total 19 years. [3] Averages of 7 years (1855–'61), last 10 years, and total 17 years.
last 10 years, and total 19 years.

EXPERIMENTS on the GROWTH of BARLEY year after year on the same LAND, without

APPENDIX-TABLE V. Total

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure,

PLOTS.	HARVESTS.											
	1852.	**1853.**	**1854.**	**1855.**	**1856.**	**1857.**	**1858.**	**1859.**	**1860.**	**1861.**	**1862.**	**1863.**
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 O.	1585	1552	1963	1773	812	1453	1207	775	753	941	899	1276
2 O.	1605	1867	2298	1973	886	1861	1657	1179	884	1410	1253	1814
3 O.	1558	1586	2021	1918	936	1741	1396	872	847	1084	1094	1557
4 O.	1819	2017	2374	2067	1018	2191	1780	1197	1013	1648	1428	1868
Means	1642	1755	2164	1933	913	1811	1510	1006	874	1271	1168	1629
1 A.	2088	2285	2763	2413	1432	2133	1771	919	1501	1745	1821	2406
2 A.	2212	2352	3437	2639	1467	3161	2879	2034	2371	3073	2791	3511
3 A.	2091	2259	2897	2504	1577	2302	1946	977	1540	1799	2049	2748
4 A.	2368	2309	3428	2659	1599	3216	2897	2017	2375	3059	2725	3210
Means	2190	2301	3131	2561	1519	2703	2374	1487	1947	2419	2346	2969
1 AA.	2486	2394	3313	2640	2061	2725	2198	1237	1395	1986	1874	2753
2 AA.	2483	2435	3643	2707	1687	3696	3131	2140	2338	3178	2908	3515
3 AA.	2431	2358	3075	2586	1489	2708	2311	1235	1672	2038	2234	3042
4 AA.	2532	2590	3539	2582	1886	3677	3155	2092	2501	3169	2824	3429
Means	2483	2444	3393	2629	1781	3202	2699	1676	1977	2593	2460	3185
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	2193	2318	3388	2668	1870	3547	2980	2245	1773	3209	2389	3005
2 C.	2057	2243	3444	2857	1916	3521	3174	2284	2051	3227	2619	3213
3 C.	1907	2113	3221	2659	1711	3417	2887	2001	1943	2944	2118	3089
4 C.	2098	2302	3413	2783	1841	3536	3162	2135	2238	3111	2634	3159
Means	2064	2244	3366	2742	1834	3505	3051	2166	2001	3123	2440	3117
1 N.	(1437)	2044	2740	2727	1675	2634	2144	1400	1546	2215	2075	2875
2 N.		2071	3113	2696	2225	3226	2480	1525	1703	2345	2184	3016
M.				1730	1016	1379	1476	1055	618	1563	1443	1562
5 O.	(2034)	1493	1748	1759	1009	1764	1441	955	593	1598	1088	1641
5 A.	2034	2306	2959	2596	1700	3061	2754	1857	2188	2808	2635	2944
6 {1	1627	1521	1998	2074	910	1899	1496	954	719	940	1031	1527
6 {2	1451	1555	1904	1982	923	1738	1422	831	718	1000	1182	1613
7	1844	2136	3127	2765	1656	2915	3118	2362	2319	3169	2936	3473

(1) Averages of 4 years, 4 years, and 8 years. (2) Averages of 9 years (1853–'61), last 10 years,

(4) Averages of 9 years (1853–'61),

Manure, and with different descriptions of Manure. Hoos Field, Rothamsted.

Corn per Acre—lbs.

at the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.]

HARVESTS.								AVERAGE ANNUAL.			PLOTS.
1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1379	1018	858	978	873	840	751	973	1281	985	1133	1 O.
1790	1252	1216	1386	1060	1079	986	1329	1562	1317	1439	2 O.
1526	1237	1041	962	824	1097	928	1125	1396	1139	1268	3 O.
1949	1349	1323	1180	998	1286	1053	1438	1712	1387	1550	4 O.
1661	1214	1109	1126	939	1075	929	1216	1488	1207	1347	Means
2258	1666	1474	1686	1136	1599	1539	2129	1908	1771	1840	1 A.
3399	2636	2809	2458	2092	2849	2404	2672	2563	2762	2662	2 A.
2563	1872	1541	1808	1406	1994	1733	2231	1989	1995	1992	3 A.
3316	2549	2636	2454	1978	2848	2197	2769	2593	2668	2630	4 A.
2884	2181	2115	2101	1653	2322	1968	2450	2263	2299	2281	Means
2430	1875	1633	1669	1500	1773	1630	2250	2244	1939	2091	1 AA.
3300	2600	2913	2464	2492	2845	2655	2771	2744	2846	2795	2 AA.
2600	1920	1631	1814	1578	1929	1803	2098	2190	2065	2128	3 AA.
3299	2684	2954	2573	2586	2929	2571	2683	2772	2853	2813	4 AA.
2907	2270	2283	2130	2039	2369	2165	2451	2487	2426	2457	Means
2573	1948	2054	1811	1644	2029	1963	2721	(1) 2097	2089	2093 (1)	1 AAS.
3190	2564	2939	2490	2585	2924	2593	2904	(1) 2796	2752	2774 (1)	2 AAS.
2933	2299	2341	2173	2061	2429	2424	2731	(1) 2437	2411	2424 (1)	3 AAS.
3465	2751	2888	2543	2669	3118	2755	2886	(1) 2912	2857	2884 (1)	4 AAS.
3040	2391	2556	2254	2240	2625	2434	2811	2560	2527	2544	Means
2828	2508	2631	2209	2122	2482	2429	2561	2619	2516	2568	1 C.
3039	2503	2741	2594	2044	2867	2437	2445	2677	2650	2664	2 C.
2923	2666	2518	2221	1999	2584	2260	2695	2480	2507	2494	3 C.
3153	2648	2834	2411	2051	3065	2569	2809	2662	2733	2698	4 C.
2986	2581	2681	2359	2054	2750	2424	2628	2610	2602	2606	Means
2360	2101	1910	1866	1410	2064	1966	2451	(2) 2124	2108	2116 (2)	1 N.
2710	2226	2266	2008	1443	2218	2278	2650	(2) 2376	2300	2336 (2)	2 N.
1519	1145	1048	1161	821	957	915	1275	(3) 1262	1185	1217 (3)	M.
1610	1290	1248	1111	868	1378	835	1143	(4) 1373	1221	1293 (4)	5 O.
3015	2710	2461	2001	2114	2931	2424	2604	2426	2584	2505	5 A.
1461	1180	899	953	846	857	851	1091	1414	1070	1242	1 } 6
1454	1084	948	1121	876	873	853	1375	1352	1138	1245	2 } 6
3672	2923	3065	2614	2539	2746	2734	3243	2541	2995	2768	7

and total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.
last 10 years, and total 19 years.

EXPERIMENTS on the GROWTH of BARLEY year after year on the same LAND, without

APPENDIX-TABLE VI. Straw

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure,

PLOTS.	HARVESTS.											
	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
1 O.	16⅝	18	21¾	17⅝	8¾	12¾	10⅞	9⅛	7½	11	9¾	11⅜
2 O.	16½	17⅛	23¼	17¾	8¾	15⅝	14⅞	12¼	8⅞	13¼	12⅞	15⅝
3 O.	16½	17¼	20⅞	17½	9⅛	15	12¼	9¾	8½	11½	10⅞	13⅜
4 O.	19½	20½	23⅛	18	9⅜	17⅛	16⅛	12¼	9⅜	15⅜	13½	15⅜
Means	17¼	18¼	22¼	17⅝	9	15⅛	13½	10⅝	8⅝	12¾	11½	13⅞
1 A.	22⅞	23¾	30¼	24⅛	17⅛	17¾	15½	11½	14⅞	19⅝	20⅜	21⅜
2 A.	26	25½	40⅞	29⅜	21½	26¾	28¾	24⅞	25¼	29¾	32⅜	34
3 A.	23⅝	25⅛	33¾	27½	17⅞	21⅜	17⅞	13½	16¼	21½	23¼	26¼
4 A.	27⅞	26⅝	40½	31	21¼	27⅞	29⅜	27¼	26⅝	30½	31⅝	32
Means	25⅛	25¼	36⅜	28	19½	23½	22⅛	19¼	20¾	25⅜	26¾	28⅜
1 AA.	26⅞	26⅛	37⅞	32⅛	24½	23½	19⅛	14½	13½	22	21¼	25⅛
2 AA.	28⅜	28⅜	44⅜	38⅝	31⅝	32⅞	32⅝	26½	24¼	31⅝	31½	32½
3 AA.	26⅜	27¼	37⅞	34	26⅛	26	22⅛	16⅛	18⅛	24⅛	24¾	27⅞
4 AA.	28⅜	31⅝	49	39⅞	33	36¼	35¾	30⅝	29	33⅝	33⅛	34¾
Means	27½	28⅜	42¼	36⅛	28¾	29⅝	27½	21⅞	21¼	27⅞	27⅝	30
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	24⅝	26⅞	43¼	36⅛	26	33⅛	30¾	26⅞	17⅞	27⅞	26	28⅝
2 C.	23¾	25⅝	44⅛	36⅛	31½	[illegible]	33⅞	28¾	20⅝	30⅜	27¼	30⅛
3 C.	21⅞	25¼	41¼	35⅞	26½	30⅞	30¾	25⅝	20⅛	30¾	23⅞	29⅞
4 C.	24⅛	27½	42⅛	37⅝	30½	33⅛	35	29½	22¾	31	28⅞	30¾
Means	23½	26¼	42¾	36½	28⅝	32⅝	32⅝	27¾	20⅜	30	26½	29⅞
1 N.	(15¼)	23⅛	33⅜	27	19⅝	24⅝	20⅛	18¾	16¾	27¼	24¼	30¼
2 N.		25⅜	38¼	33¼	28¾	32	23⅝	21¼	18⅝	29⅝	24¾	29⅞
M.				15¼	10⅝	10⅜	12⅜	10⅞	7¼	15⅛	14½	19½
5 O.	(25⅓)	15¾	20¼	14⅝	10⅜	13¼	12½	10½	6⅞	17½	10½	15¼
5 A.	25⅛	24	35¾	31	22¾	27⅝	28⅝	26⅛	25½	31⅞	31⅝	34
6 {1	17⅛	16½	22½	18⅛	9¼	16⅛	12	11¼	7½	9⅞	10⅜	13½
6 {2	14⅛	15⅞	20¾	16¾	9½	14⅝	11⅜	10	7¾	10	11⅝	14⅜
7	18½	22¾	37¼	27½	19¾	23⅝	31⅜	28½	25⅜	31⅝	34¼	33⅛

(1) Averages of 4 years, 4 years, and 8 years.

(2) Averages of 9 years (1853–'61), last 10 years,

(4) Averages of 9 years (1853–'61),

Manure, and with different descriptions of **Manure**. Hoos Field, Rothamsted.

(and Chaff) per Acre—Cwts.

at the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.]

HARVESTS.								AVERAGE ANNUAL.			PLOTS.
1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	
Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	
12¾	8⅛	9½	10¼	11⅝	11	6⅝	11	13⅜	10¼	11¾	1 O.
15⅝	9⅛	12⅝	12¼	9⅜	10⅜	8	12¼	14⅞	11⅞	13⅜	2 O.
13⅜	9¾	10¼	10⅛	8⅝	11	8½	11¼	13⅞	10¾	12¼	3 O.
16¾	10	12⅞	12	10⅛	12⅞	9⅜	14	16⅛	12⅝	14⅜	4 O.
14⅝	9¼	11¼	11⅛	9⅞	11¼	8⅛	12⅛	14½	11⅜	12⅞	Means
20⅜	13	15⅜	17¼	12¼	18¼	12½	23⅛	19¾	17⅜	18½	1 A.
32½	21⅝	28⅛	28⅝	19⅜	32	17⅞	28⅛	27⅞	27½	27⅝	2 A.
19¼	16	16¾	19⅜	14⅞	20¾	15	25⅜	21⅞	19¾	20¾	3 A.
34⅞	22½	27⅜	25½	20⅞	34⅜	18⅝	32½	28⅞	28	28½	4 A.
26¾	18¼	21¾	22⅝	16¾	26⅜	16	27¼	24½	23⅛	23¾	Means
23¼	16	17¾	17⅛	14½	21½	17⅞	26¾	24	20⅛	22⅛	1 AA.
33⅛	23	28⅛	30⅞	21⅞	34⅞	23¾	32⅛	31⅞	29⅛	30½	2 AA.
26⅞	17	18⅛	20¾	16¼	22¾	20⅞	25⅜	25¾	22¼	24	3 AA.
37¼	24⅞	28¼	28⅜	25⅝	38⅛	18¼	32⅝	34¾	30⅛	32⅜	4 AA.
30⅛	20¼	23⅛	24¼	19⅝	29¼	20¼	29¼	29	25⅜	27¼	Means
26⅛	22⅜	20⅝	18½	16⅞	23¾	17	29¾	(1) 21⅞	21⅞	21⅞ (1)	1 AAS.
33½	23¼	30¼	29½	25¼	37⅛	20⅛	36⅛	29⅛	29⅝	29⅜	2 AAS.
30¼	20⅜	25	23⅜	22	30⅝	20½	31⅛	24¾	26⅛	25⅜	3 AAS.
40¾	25½	29½	28¼	26⅝	42½	20¾	38	31	32	31½	4 AAS.
32⅝	22⅞	26⅜	24⅞	22⅝	33½	19⅝	33¾	26⅝	27⅜	27	Means
26⅛	21½	24⅛	25½	19⅛	27	17¼	27½	29⅜	24¼	26⅞	1 C.
31⅞	21⅞	24½	25⅝	19⅝	33⅛	17⅞	27⅞	30⅞	26	28⅜	2 C.
31	22	24⅜	22¼	19¾	30½	18⅜	30⅞	28⅞	25¼	27⅛	3 C.
34⅞	22	27⅝	24¼	21⅛	35⅛	20⅜	32	31¼	27¾	29½	4 C.
31	21⅞	25⅛	24⅜	19⅞	31⅜	18½	29⅝	30⅛	25¾	28	Means
24⅛	18½	21⅛	21⅛	18⅞	24	13¼	29¼	(2) 23⅜	22½	22⅞ (2)	1 N.
27¾	21½	23⅞	21¾	17⅛	27⅝	19⅛	31½	27⅞	24½	26⅛	2 N.
13⅞	9⅜	12⅜	12	10⅞	11⅝	8⅞	14¾	(3)(11¾	12¾	12⅜) (3)	M.
14⅞	10¾	10⅜	10⅜	8½	15½	4⅜	13⅛	(4)(13⅜	11⅜	12⅜) (4)	5 O.
33⅞	24⅞	28	22⅜	20⅝	36⅛	21⅜	29⅝	27⅞	28¼	28	5 A.
13⅝	8¾	10½	9⅝	10½	9⅞	7¾	13	14	10¾	12⅜	1 } 6
13⅞	8⅞	9½	10⅞	10⅞	10⅜	7⅞	13⅝	13	11¼	12⅛	2 } 6
37⅜	25⅜	31½	27⅛	24½	28¾	19¾	37⅛	26⅝	29⅞	28¼	7

and total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.
last 10 years, and total 19 years.

EXPERIMENTS on the GROWTH of BARLEY year after year on the same LAND, without

APPENDIX-TABLE VII. Total Produce

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure,

PLOTS.	HARVESTS.											
	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 O.	3445	3562	4405	3745	1797	2878	2424	1800	1598	2166	1987	2545
2 O.	3459	3783	4898	3955	1865	3606	3327	2559	1877	2900	2701	3569
3 O.	3405	3521	4353	3873	1961	3426	2771	1962	1802	2369	2309	3050
4 O.	4008	4312	4969	4082	2075	4111	3590	2567	2093	3366	2941	3596
Means	3579	3794	4656	3914	1924	3505	3028	2222	1842	2700	2484	3190
1 A.	4652	4950	6155	5148	3347	4118	3506	2204	3166	3945	4106	4806
2 A.	5127	5202	8017	5929	3874	6161	6099	4814	5196	6411	6416	7319
3 A.	4730	5079	6672	5579	3574	4702	3951	2487	3355	4212	4658	5691
4 A.	5487	5284	7958	6134	3981	6336	6192	5067	5355	6472	6273	6791
Means	4999	5129	7200	5697	3694	5329	4937	3643	4268	5260	5363	6152
1 AA.	5490	5324	7548	6242	4801	5360	4345	2857	2905	4449	4247	5561
2 AA.	5662	5615	8619	7027	5233	7383	6791	5105	5053	6721	6443	7148
3 AA.	5378	5405	7315	6388	4414	5618	4791	3035	3702	4743	5003	6168
4 AA.	5714	6134	9026	7054	5582	7734	7160	5517	5746	6937	6529	7323
Means	5561	5619	8127	6678	5008	6524	5772	4128	4352	5713	5556	6550
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	4949	5323	8238	6720	4780	7262	6425	5260	3771	6332	5299	6214
2 C.	4713	5110	8388	6904	5447	7266	6964	5509	4356	6625	5669	6593
3 C.	4351	4943	7848	6676	4673	6877	6337	4866	4198	6392	4786	6429
4 C.	4796	5386	8125	6993	5257	7241	7082	5440	4783	6576	5872	6599
Means	4702	5190	8150	6823	5039	7161	6702	5269	4277	6481	5407	6459
1 N.	(3143)	4631	6475	5757	3877	5389	4399	3500	3416	5260	4793	6265
2 N.		4906	7400	6416	5450	6816	5125	3905	3793	5665	4959	6366
M.				3440	2206	2538	2856	2275	1433	3263	3061	3740
5 O.	(4843)	3263	4013	3394	2169	3254	2846	2125	1363	3563	2266	3354
5 A.	4843	4996	6864	6066	4247	6161	5954	4777	5038	6373	6175	6749
6 {1	3550	3371	4519	4100	1952	3711	2846	2212	1560	2048	2189	3042
6 {2	3030	3336	4221	3857	1981	3375	2693	1948	1581	2117	2480	3221
7	3920	4682	7298	5852	3866	5564	6635	5558	5156	6715	6774	7185

(1) Averages of 4 years, 4 years, and 8 years.

(2) Averages of 9 years (1853–'61), last 10 years,

(4) Averages of 9 years (1853–'61),

Manure, and with different descriptions of Manure. Hoos Field, Rothamsted.

(Corn, Straw and Chaff) per Acre—lbs.

at the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.

HARVESTS.								AVERAGE ANNUAL.			
1864.	**1865.**	**1866.**	**1867.**	**1868.**	**1869.**	**1870.**	**1871.**	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	PLOTS.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
2809	1924	1928	2124	2173	2075	1489	2208	2782	2126	2454	1 O.
3533	2268	2636	2759	2110	2238	1884	2694	3223	2639	2931	2 O.
3020	2325	2191	2098	1789	2333	1882	2380	2944	2338	2641	3 O.
3829	2464	2759	2526	2126	2729	2101	3002	3517	2807	3162	4 O.
3298	2245	2378	2377	2049	2344	1839	2571	3116	2478	2797	Means
4533	3127	3200	3611	2507	3640	2945	4712	4119	3719	3919	1 A.
7042	5061	5955	5658	4255	6430	4412	5820	5683	5837	5760	2 A.
4726	3658	3412	3977	3074	4319	3406	5080	4434	4200	4317	3 A.
7225	5075	5704	5304	4311	6701	4287	6404	5827	5808	5817	4 A.
5881	4230	4568	4637	3537	5272	3762	5504	5016	4891	4953	Means
5040	3668	3628	3589	3130	4181	3628	5250	4932	4192	4562	1 AA.
7008	5180	6068	5917	4937	6750	5315	6371	6321	6114	6217	2 AA.
5613	3820	3661	4144	3401	4477	4141	4933	5079	4536	4808	3 AA.
7469	5469	6117	5753	5454	7194	4621	6333	6660	6226	6443	4 AA.
6282	4534	4869	4851	4231	5651	4426	5722	5748	5267	5508	Means
5501	4453	4357	3884	3537	4689	3868	6051	(1) 4549	4536	4543 (1)	1 AAS.
6945	5172	6327	5790	5410	7082	4851	6954	(1) 6059	6074	6067 (1)	2 AAS.
6316	4582	5144	4793	4524	5864	4724	6221	(1) 5209	5333	5271 (1)	3 AAS.
8025	5609	6198	5708	5644	7881	5073	7146	(1) 6385	6436	6411 (1)	4 AAS.
6697	4954	5507	5044	4779	6379	4629	6594	5551	5595	5573	Means
5758	4909	5337	5064	4267	5512	4358	5637	5906	5236	5571	1 C.
6604	4959	5487	5460	4238	6571	4437	5570	6128	5559	5844	2 C.
6396	5134	5242	4711	4213	5993	4324	6153	5716	5338	5527	3 C.
7061	5117	5929	5121	4414	7001	4857	6394	6168	5837	6002	4 C.
6455	5030	5499	5089	4283	6269	4494	5939	5980	5493	5736	Means
5065	4174	4275	4234	3530	4759	3456	5726	(2) 4745	4628	4683 (2)	1 N.
5820	4629	4941	4438	3366	5313	4413	6175	(2) 5497	5042	5258 (2)	2 N.
3079	2195	2436	2499	2044	2265	1903	2920	(3)(2573	2614	2597)(3)	M.
3273	2490	2443	2271	1826	3111	1323	2618	(4)(2888	2498	2682)(4)	5 O.
6815	5490	5591	4511	4419	6979	4817	5927	5542	5747	5644	5 A.
2986	2159	2078	2026	2019	1957	1720	2554	2987	2273	2630	1 } 6
3008	2076	2017	2344	2097	2031	1740	2896	2814	2391	2603	2 } 6
7852	5769	6594	5652	5281	5959	4950	7401	5525	6342	5933	7

and total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.
last 10 years, and total 19 years.

EXPERIMENTS on the GROWTH of BARLEY year after year on the same LAND, without

APPENDIX-TABLE VIII. Increase by Manure (over the

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure

PLOTS	HARVESTS. 1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 O.												
2 O.	– 1	330	317	49	25	185	305	314	148	470	288	412
3 O.	–48	49	40	– 6	75	65	44	7	111	144	129	155
4 O.	213	480	393	143	157	515	428	332	277	708	463	466
Means	55	286	250	62	86	255	259	218	179	441	293	344
1 A.	482	748	782	519	571	457	419	54	765	805	856	1004
2 A.	606	815	1456	715	606	1485	1527	1169	1635	2133	1826	2109
3 A.	485	722	916	580	716	626	594	112	804	859	1084	1346
4 A.	762	772	1447	735	738	1540	1545	1152	1639	2119	1760	1808
Means	584	764	1150	637	658	1027	1021	622	1211	1479	1382	1567
1 AA.	880	857	1332	716	1200	1049	846	372	659	1046	909	1351
2 AA.	877	898	1662	783	826	2020	1779	1275	1602	2238	1943	2113
3 AA.	825	821	1094	662	628	1032	959	370	936	1098	1269	1640
4 AA.	926	1053	1558	658	1025	2001	1803	1227	1765	2229	1859	2027
Means	877	907	1412	705	920	1526	1347	811	1241	1653	1495	1783
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	587	781	1407	744	1009	1871	1628	1380	1037	2269	1424	1603
2 C.	451	706	1463	933	1055	1845	1822	1419	1315	2287	1654	1811
3 C.	301	576	1240	735	850	1741	1535	1136	1207	2004	1153	1687
4 C.	492	765	1432	859	980	1860	1810	1270	1502	2171	1669	1757
Means	458	707	1386	818	974	1829	1699	1301	1265	2183	1475	1715
1 N. }	- (169) {	507	759	803	814	958	792	535	810	1275	1110	1473
2 N. }		534	1132	772	1364	1550	1128	660	967	1405	1219	1614
M.				–194	155	–297	124	190	– 118	623	478	160
5 O.	(428)	– 44	–233	–165	148	88	89	90	–143	658	123	239
5 A.	428	769	978	672	839	1385	1402	992	1452	1868	1670	1542
6 {1 2	–155	18	– 77	58	62	62	70	– 34	– 18	60	217	211
7	238	599	1146	841	795	1239	1766	1497	1583	2229	1971	2071

([1]) Averages of 4 years, 4 years, and 8 years.

([2]) Averages of 9 years (1853–'61), last 10 years,

([4]) Averages of 9 years (1853–'61),

Manure, and with different descriptions of Manure. Hoos Field, Rothamsted.

Mean of Plots 1 O. and 6–1), of Total Corn, per Acre—lbs.

at the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.]

HARVESTS.								AVERAGE ANNUAL.			PLOTS.
1864.	**1865.**	**1866.**	**1867.**	**1868.**	**1869.**	**1870.**	**1871.**	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
											1 O.
370	153	337	420	200	230	185	297	214	289	252	2 O.
106	138	162	– 4	– 36	248	127	93	48	112	80	3 O.
529	250	444	214	138	437	252	406	365	360	363	4 O.
335	180	314	210	101	305	188	265	209	254	232	Means
838	567	595	720	276	750	738	1097	560	744	652	1 A.
1979	1537	1930	1492	1232	2000	1603	1640	1215	1735	1475	2 A.
1143	773	662	842	546	1145	932	1199	641	967	804	3 A.
1896	1450	1757	1488	1118	1999	1396	1737	1245	1641	1443	4 A.
1464	1082	1236	1136	793	1474	1167	1418	915	1272	1094	Means
1010	776	754	703	640	924	829	1218	896	911	904	1 AA.
1880	1501	2034	1498	1632	1996	1854	1739	1396	1819	1608	2 AA.
1180	821	752	848	718	1080	1001	1066	843	1038	941	3 AA.
1879	1585	2075	1607	1726	2080	1770	1651	1425	1826	1625	4 AA.
1487	1171	1404	1164	1179	1520	1364	1419	1140	1399	1270	Means
1153	849	1175	845	784	1180	1162	1689	(1) 1006	1204	1105 (1)	1 AAS.
1770	1465	2060	1524	1725	2075	1792	1872	1705	1866	1786	2 AAS.
1513	1200	1462	1207	1201	1580	1623	1699	1346	1526	1436	3 AAS.
2045	1652	2009	1577	1809	2269	1954	1854	1821	1972	1896	4 AAS.
1620	1292	1677	1288	1380	1776	1633	1779	1470	1642	1556	Means
1408	1409	1752	1243	1262	1633	1628	1529	1271	1489	1380	1 C.
1619	1404	1862	1628	1184	2018	1636	1413	1330	1623	1477	2 C.
1503	1567	1639	1255	1139	1735	1459	1663	1133	1480	1307	3 C.
1733	1549	1955	1445	1191	2216	1768	1777	1314	1706	1510	4 C.
1566	1482	1802	1393	1194	1901	1623	1596	1262	1575	1419	Means
940	1002	1031	900	550	1215	1165	1419	(2) 806	1081	950 (2)	1 N.
1290	1127	1387	1042	583	1369	1477	1618	1057	1273	1170	2 N.
99	46	169	195	– 39	108	114	243	(3) 69	157	121 (3)	M.
190	191	369	145	8	529	34	111	(4) 54	194	128 (4)	5 O.
1595	1611	1582	1035	1254	2082	1623	1572	1079	1557	1318	5 A.
34	– 15	69	155	16	24	52	343	5	111	58	1, 2 } 6
2252	1824	2186	1648	1679	1897	1933	2211	1193	1967	1580	7

and total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.
last 10 years, and total 19 years.

Experiments on the Growth of Barley year after year on the same Land, without

APPENDIX-TABLE IX. Increase by Manure (over the Mean

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure,

PLOTS.	HARVESTS.											
	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 O.												
2 O.	− 38	− 14	118	− 17	− 35	126	386	238	150	323	325	363
3 O.	− 45	5	− 150	− 44	11	66	91	− 52	112	118	92	101
4 O.	297	365	113	16	43	301	526	228	237	551	390	336
Means	71	119	27	− 15	6	164	334	138	166	331	269	267
1 A.	672	735	910	706	901	366	451	143	822	1033	1162	1008
2 A.	1023	920	2098	1291	1393	1381	1936	1638	1982	2171	2502	2416
3 A.	747	890	1293	1076	983	781	721	368	972	1246	1486	1551
4 A.	1227	1045	2048	1476	1368	1501	2011	1908	2137	2246	2425	2189
Means	917	898	1587	1137	1161	1007	1280	1014	1478	1674	1894	1791
1 AA.	1112	1000	1753	1603	1726	1016	863	478	667	1296	1250	1416
2 AA.	1287	1250	2494	2321	2532	2068	2376	1823	1872	2376	2412	2241
3 AA.	1055	1117	1758	1803	1911	1291	1196	658	1187	1538	1646	1734
4 AA.	1290	1614	3065	2473	2682	2438	2721	2283	2402	2601	2582	2502
Means.	1186	1245	2253	2050	2213	1703	1789	1311	1532	1953	1973	1973
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	864	1075	2368	2053	1896	2096	2161	1873	1155	1956	1787	1817
2 C.	764	937	2462	2048	2517	2126	2506	2083	1462	2231	1927	1988
3 C.	552	900	2145	2018	1948	1841	2166	1723	1412	2281	1545	1948
4 C.	806	1154	2230	2211	2402	2086	2636	2163	1702	2298	2115	2048
Means	747	1017	2301	2083	2191	2037	2367	1961	1433	2192	1844	1950
1 N.	(− 186)	657	1253	1031	1188	1136	971	958	1027	1878	1595	1998
2 N.		905	1805	1721	2211	1971	1361	1238	1247	2153	1652	1958
M.				− 289	176	− 460	96	78	− 28	533	495	786
5 O.	(917)	− 160	− 217	− 364	146	− 129	121	28	− 73	798	55	321
5 A.	917	760	1523	1471	1533	1481	1916	1778	2007	2398	2417	2413
6 {1, 2}	− 313	− 149	− 165	− 124	44	18	− 13	− 25	20	− 50	175	216
7	184	616	1689	1088	1196	1030	2233	2054	1994	2379	2715	2320

(1) Averages of 4 years, 4 years, and 8 years.

(2) Averages of 9 years (1853–'61), last 10 years,

(4) Averages of 9 years (1853–'61)

MANURE, and with different descriptions of MANURE. Hoos Field, Rothamsted.

of Plots 1 O and 6–1), of Straw (and Chaff) per Acre—lbs.

at the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.]

HARVESTS.								AVERAGE ANNUAL.			
1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	PLOTS.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
											1 O.
265	73	295	263	−186	−9	94	16	124	150	137	2 O.
16	145	25	26	−271	68	150	−94	11	26	19	3 O.
402	172	311	236	−108	275	244	215	268	248	258	4 O.
228	130	210	175	−188	111	163	46	134	141	138	Means
797	518	601	815	135	873	602	1234	674	775	724	1 A.
2165	1482	2021	2090	927	2413	1204	1799	1583	1902	1742	2 A.
685	843	746	1059	432	1157	809	1500	908	1033	970	3 A.
2431	1583	1943	1740	1097	2685	1286	2286	1697	1967	1832	4 A.
1520	1107	1328	1426	648	1782	990	1705	1215	1419	1317	Means
1132	850	870	810	394	1240	1194	1651	1151	1081	1116	1 AA.
2230	1637	2030	2343	1209	2737	1856	2251	2040	2095	2067	2 AA.
1535	957	905	1221	587	1380	1534	1486	1351	1299	1325	3 AA.
2692	1842	2038	2070	1632	3097	1246	2301	2351	2200	2276	4 AA.
1897	1322	1461	1611	956	2114	1458	1922	1723	1669	1696	Means
1450	1562	1178	963	657	1492	1101	1981	(1) 1288	1308	1298 (1)	1 AAS.
2277	1665	2243	2190	1589	2990	1454	2701	2099	2184	2141	2 AAS.
1905	1340	1678	1510	1227	2267	1496	2141	1608	1783	1696	3 AAS.
3082	1915	2185	2055	1739	3595	1514	2911	2309	2440	2275	4 AAS.
2179	1621	1826	1680	1203	2586	1391	2434	1826	1929	1877	Means
1452	1458	1581	1745	909	1862	1125	1727	1750	1546	1648	1 C.
2087	1513	1621	1756	958	2536	1196	1776	1914	1736	1825	2 C.
1995	1525	1599	1580	978	2241	1260	2109	1699	1658	1678	3 C.
2430	1526	1970	1600	1127	2768	1484	2236	1969	1930	1950	4 C.
1991	1506	1693	1620	993	2352	1266	1962	1833	1718	1775	Means
1227	1130	1240	1258	884	1527	686	1926	(2) 1122	1347	1241 (2)	1 N.
1632	1460	1550	1320	687	1927	1331	2176	1624	1569	1595	2 N.
82	107	263	228	13	140	184	296	(3) (15	257	157)(3)	M.
185	257	70	50	−278	565	−316	126	(4) (17	104	62)(4)	5 O.
2322	1837	2005	1400	1069	2880	1589	1974	1578	1991	1784	5 A.
76	49	−56	113	−15	−10	83	172	−76	80	2	1, 2 } 6
2702	1903	2404	1928	1506	2045	1412	2809	1447	2174	1811	7

and total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.

ast 10 years and total 19 years,

EXPERIMENTS on the GROWTH of BARLEY year after year on the same LAND, withou

APPENDIX-TABLE X. Increase by Manure (over the Mean of Plots 1 (

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure

PLOTS.	HARVESTS. 1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 O.												
2 O.	− 39	316	435	32	− 10	311	691	552	298	793	613	775
3 O.	− 93	54	−110	− 50	86	131	135	− 45	223	262	221	256
4 O.	510	845	506	159	200	816	954	560	514	1259	853	802
Means	126	405	277	47	92	419	593	356	345	771	562	611
1 A.	1154	1483	1692	1225	1472	823	870	197	1587	1838	2018	2012
2 A.	1629	1735	3554	2006	1999	2866	3463	2807	3617	4304	4328	4525
3 A.	1232	1612	2209	1656	1699	1407	1315	480	1776	2105	2570	2897
4 A.	1989	1817	3495	2211	2106	3041	3556	3060	3776	4365	4185	3997
Means	1501	1662	2738	1775	1819	2034	2301	1636	2689	3153	3275	3358
1 AA.	1992	1857	3085	2319	2926	2065	1709	850	1326	2342	2159	2767
2 AA.	2164	2148	4156	3104	3358	4088	4155	3098	3474	4614	4355	4354
3 AA.	1880	1938	2852	2465	2539	2323	2155	1028	2123	2636	2915	3374
4 AA.	2216	2667	4563	3131	3707	4439	4524	3510	4167	4830	4441	4529
Means	2063	2153	3664	2755	3133	3229	3136	2122	2773	3606	3468	3756
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	1451	1856	3775	2797	2905	3967	3789	3253	2192	4225	3211	3420
2 C.	1215	1643	3925	2981	3572	3971	4328	3502	2777	4518	3581	3799
3 C.	853	1476	3385	2753	2798	3582	3701	2859	2619	4285	2698	3635
4 C.	1298	1919	3662	3070	3382	3946	4446	3433	3204	4469	3784	3805
Means	1204	1724	3687	2900	3164	3867	4066	3262	2698	4374	3319	3665
1 N.	(- 355){	1164	2012	1834	2002	2094	1763	1493	1837	3153	2705	3471
2 N.		1439	2937	2493	3575	3521	2489	1898	2214	3558	2871	3572
M.				−483	331	−757	220	268	−146	1156	973	946
5 O.	(1345)	- 204	- 450	- 529	294	− 41	210	118	- 216	1456	178	560
5 A.	1345	1529	2501	2143	2372	2866	3318	2770	3459	4266	4087	3955
6{1 2	−468	- 131	- 242	− 66	106	80	57	- 59	2	10	392	427
7	422	1215	2835	1929	1991	2269	3999	3551	3577	4608	4686	4391

(1) Averages of 4 years, 4 years, and 8 years.

(2) Averages of 9 years (1853–'61), last 10 year

(4) Averages of 9 years (1853–'61

anure, and with different descriptions of Manure. Hoos Field, Rothamsted.

nd 6–1), of total produce (Corn, Straw, and Chaff) per Acre—lbs.

the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto. p. 179.]

HARVESTS.								AVERAGE ANNUAL.			PLOTS.
1864.	**1865.**	**1866.**	**1867.**	**1868.**	**1869.**	**1870.**	**1871.**	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
											1 O.
635	226	632	683	14	221	279	313	338	439	389	2 O.
122	283	187	22	-307	316	277	- 1	59	138	99	3 O.
931	422	755	450	30	712	496	621	632	607	621	4 O.
563	310	525	385	- 88	416	351	311	343	395	370	Means
1635	1085	1196	1535	411	1623	1340	2331	1234	1519	1376	1 A.
4144	3019	3951	3582	2159	4413	2807	3439	2798	3637	3217	2 A.
1828	1616	1408	1901	978	2302	1801	2699	1549	2000	1774	3 A.
4327	3033	3700	3228	2215	4684	2682	4023	2942	3608	3275	4 A.
2984	2188	2564	2562	1441	3256	2158	3123	2130	2691	2411	Means
2142	1626	1624	1513	1034	2164	2023	2869	2047	1992	2020	1 AA.
4110	3138	4064	3841	2841	4733	3710	3990	3436	3914	3675	2 AA.
2715	1778	1657	2069	1305	2460	2535	2552	2194	2336	2265	3 AA.
4571	3427	4113	3677	3358	5177	3016	3952	3776	4026	3901	4 AA.
3385	2492	2865	2775	2135	3634	2821	3341	2863	3067	2965	Means
2603	2411	2353	1808	1441	2672	2263	3670	(1) 2294	2512	2403 (1)	1 AAS.
4047	3130	4323	3714	3314	5065	3246	4573	3804	4050	3927	2 AAS.
3418	2540	3140	2717	2428	3847	3119	3840	2954	3309	3132	3 AAS.
5127	3567	4194	3632	3548	5864	3468	4765	4130	4412	4271	4 AAS.
3799	2912	3503	2968	2683	4362	3024	4212	3296	3571	3433	Means
2860	2867	3333	2988	2171	3495	2753	3256	3021	3035	3028	1 C.
3706	2917	3483	3384	2142	4554	2832	3189	3244	3359	3302	2 C.
3498	3092	3238	2635	2117	3976	2719	3772	2832	3138	2985	3 C.
4163	3075	3925	3045	2318	4984	3252	4013	3283	3636	3460	4 C.
3557	2988	3495	3013	2187	4252	2889	3558	3095	3293	3194	Means
2167	2132	2271	2158	1434	2742	1851	3345	(2) 1928	2428	2191 (2)	1 N.
2922	2587	2937	2362	1270	3296	2808	3794	2681	2842	2765	2 N.
181	153	432	423	- 52	248	298	539	(3) (84	414	278)(3)	M.
375	448	439	195	- 270	1094	- 282	237	(4) (71	298	190)(4)	5 O.
3917	3448	3587	2435	2323	4962	3212	3546	2657	3548	3102	5 A.
110	. 34	13	268	1	14	135	515	- 71	191	60	1, 2 } 6
4954	3727	4590	3576	3185	3942	3345	5020	2640	4141	3391	7

nd total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.

st 10 years, and total 19 years.

EXPERIMENTS on the GROWTH of BARLEY year after year on the same LAND, withou

APPENDIX-TABLE XI. Offa

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure

PLOTS.	HARVESTS.											
	1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
1 O.	11·5	17·0	4·5	8·9	19·3	6·9	7·7	16·5	11·6	10·3	7·6	4·0
2 O.	6·6	5·7	4·6	3·6	7·0	6·1	6·6	15·6	10·6	5·8	10·0	3·3
3 O.	13·3	10·5	3·3	4·1	15·9	3·6	7·4	10·8	10·2	8·8	7·2	3·6
4 O.	8·1	8·6	4·6	4·8	9·5	2·5	6·4	15·4	7·9	3·6	8·9	3·1
Means	9·9	10·5	4·3	5·3	12·9	4·8	7·0	14·6	10·1	7·1	8·4	3·5
1 A.	11·6	12·5	7·9	6·0	18·1	5·6	5·9	25·0	11·1	10·8	17·3	5·1
2 A.	13·3	11·1	4·6	7·5	9·0	2·9	4·1	15·6	7·2	4·4	7·4	2·9
3 A.	13·7	17·5	7·3	7·6	12·9	4·1	5·2	21·8	8·1	6·4	15·1	4·1
4 A.	13·0	13·5	4·2	5·6	8·5	2·2	4·2	14·3	6·7	3·7	5·8	2·6
Means	12·9	13·7	6·0	6·7	12·1	3·7	4·8	19·2	8·3	6·3	11·4	3·7
1 AA.	13·7	14·5	10·9	8·4	17·7	5·2	4·2	21·0	8·5	9·5	18·8	4·2
2 AA.	14·5	11·5	9·9	7·2	16·0	3·7	4·5	17·6	5·3	6·4	4·8	4·2
3 AA.	15·0	11·1	12·2	8·9	24·2	4·2	5·4	27·3	7·9	7·2	19·5	3·2
4 AA.	10·8	13·2	8·3	6·2	10·3	5·2	4·7	15·8	6·0	6·0	7·3	2·0
Means	13·5	12·6	10·3	7·7	17·1	4·6	4·7	20·4	6·9	7·3	12·6	3·4
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	8·4	13·0	5·5	8·9	10·2	4·0	3·6	11·1	7·3	5·0	6·9	2·9
2 C.	8·7	20·2	7·4	7·3	9·2	5·1	4·9	8·1	8·3	4·9	5·1	3·5
3 C.	11·1	16·3	8·3	7·4	12·4	4·8	3·8	13·4	6·3	7·4	9·9	2·3
4 C.	7·4	13·7	7·1	8·7	12·5	5·0	4·1	19·6	7·3	7·0	7·1	2·1
Means	8·9	15·8	7·1	8·1	11·1	4·7	4·1	13·1	7·3	6·1	7·2	2·7
1 N.	(7·0)	16·0	4·1	4·9	17·1	3·9	5·9	17·2	10·5	11·3	13·4	4·4
2 N.		12·3	10·1	9·1	9·5	4·9	4·6	18·2	11·7	8·8	11·0	3·9
M.				2·1	10·2	7·0	6·0	8·8	13·8	5·2	15·9	3·1
5 O.	(9·3)	4·8	6·9	2·9	10·6	6·1	5·2	13·0	13·9	4·8	21·5	2·6
5 A.	9·3	10·0	6·1	5·1	9·8	2·3	5·9	9·9	9·7	7·2	8·7	2·8
6 {1	7·9	15·1	7·8	5·9	20·1	3·9	6·0	14·5	13·9	8·4	7·8	3·5
6 {2	8·8	11·6	6·7	3·8	15·7	6·4	6·1	18·0	15·2	7·1	19·6	4·2
7	5·8	14·4	2·8	4·1	9·3	4·8	4·0	12·4	6·8	6·4	7·6	1·9

(1) Averages of 4 years, 4 years, and 8 years. (2) Averages of 9 years (1853–'61), last 10 year

(4) Averages of 9 years (1853–'61

MANURE, and with different descriptions of MANURE. Hoos Field, Rothamsted.

Corn to 100 Dressed Corn.

at the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.]

HARVESTS.								AVERAGE ANNUAL.			PLOTS.
1864.	**1865.**	**1866.**	**1867.**	**1868.**	**1869.**	**1870.**	**1871.**	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71,	Total Period, 20 Years, 1852–'71.	
3·1	4·8	5·1	10·1	2·4	5·5	4·3	5·2	11·4	5·2	8·3	1 O.
4·0	3·1	1·7	3·9	2·8	9·0	1·9	2·6	7·2	4·2	5·8	2 O.
2·9	3·2	3·8	7·1	3·4	6·8	2·0	3·2	8·8	4·3	6·6	3 O.
2·2	2·1	4·3	5·4	2·6	5·7	2·5	3·4	7·1	4·0	5·6	4 O.
3·1	3·3	3·7	6·6	2·8	6·8	2·7	3·6	8·6	4·4	6·5	Means
4·6	3·6	6·8	7·3	4·5	9·6	1·5	5·2	11·5	6·6	9·0	1 A.
1·9	3·3	2·3	3·2	1·8	4·1	1·1	7·6	8·0	3·6	5·8	2 A.
3·4	2·8	7·4	5·5	2·5	5·0	1·4	4·1	10·5	5·1	7·8	3 A.
3·4	2·4	2·5	3·0	2·6	0·8	1·2	5·6	7·6	3·0	5·3	4 A.
3·3	3·0	4·8	4·8	2·9	4·9	1·3	5·6	9·4	4·6	7·0	Means
4·7	3·5	9·9	7·1	3·2	3·7	2·0	6·3	11·4	6·3	8·9	1 AA.
1·5	4·5	4·0	2·9	1·9	3·2	0·9	6·4	9·7	3·4	6·5	2 AA.
3·0	2·5	6·7	6·2	3·9	6·1	2·1	6·7	12·3	6·0	9·2	3 AA.
1·4	2·9	4·7	4·8	1·7	2·7	1·2	3·5	8·6	3·2	6·0	4 AA.
2·7	3·4	6·3	5·3	2·7	4·0	1·5	5·7	10·5	4·7	7·6	Means
3·8	2·9	4·5	4·9	3·1	6·4	1·7	3·6	(1) 4·0	3·7	3·9 (1)	1 AAS.
1·7	3·5	3·4	2·7	2·5	2·1	0·9	5·5	(1) 2·8	2·8	2·8 (1)	2 AAS.
2·5	2·2	6·4	3·8	1·9	5·9	1·2	5·0	(1) 3·7	3·5	3·6 (1)	3 AAS.
2·7	2·6	2·9	3·8	1·8	4·2	1·0	6·5	(1) 3·0	3·4	3·2 (1)	4 AAS.
2·7	2·8	4·3	3·8	2·3	4·7	1·2	5·1	3·4	3·3	3·4	Means
2·8	3·4	4·1	5·2	2·1	2·9	1·0	3·2	7·7	3·5	5·6	1 C.
3·1	1·8	3·4	3·6	3·2	4·0	1·0	3·7	8·4	3·2	5·8	2 C.
3·2	2·6	3·9	4·3	2·0	3·7	1·7	5·5	9·1	3·9	6·5	3 C.
4·0	2·7	4·7	3·1	2·1	2·2	1·1	4·6	9·2	3·4	6·3	4 C.
3·3	2·6	4·0	4·0	2·3	3·2	1·2	4·3	8·6	3·5	6·1	Means
3·2	4·9	6·9	6·8	4·5	7·8	1·7	4·2	(2) 10·1	5·7	7·8 (2)	1 N.
3·6	3·9	4·8	4·6	2·5	4·6	1·5	6·9	(2) 9·9	4·7	7·1 (2)	2 N.
3·9	6·4	4·4	5·1	3·3	6·8	2·8	4·7	(3) 7·6	5·6	6·4 (3)	M.
5·1	2·8	4·0	5·3	2·4	5·8	2·8	3·8	(4) 7·6	5·6	6·5 (4)	5 O.
3·1	3·6	2·2	3·8	1·6	2·2	1·3	5·8	7·5	3·5	5·5	5 A.
3·6	4·0	8·7	12·1	3·3	9·0	3·2	4·8	10·4	6·0	8·2	1 } 6
3·9	4·5	5·7	8·0	2·4	7·0	2·8	3·0	9·9	6·1	8·0	2 } 6
3·3	2·0	5·1	4·5	1·9	3·8	1·0	5·6	7·1	3·7	5·4	7

and total 19 years. (3) Averages of 7 years (1855–'61), last 10 years, and total 17 years.
last 10 years, and total 19 years.

EXPERIMENTS on the GROWTH of BARLEY year after year on the same LAND, without

APPENDIX-TABLE XII. Total

[N.B. The double vertical lines show that there was a change in the description, or quantity, of Manure,

PLOTS.	HARVESTS. 1852.	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.	1863.
1 O.	85	77	80	90	82	102	99	76	89	77	83	101
2 O.	87	97	88	99	90	107	99	85	89	95	87	103
3 O.	84	82	87	98	91	103	102	80	89	84	90	104
4 O.	83	88	92	103	96	114	98	87	94	96	94	108
Means	85	86	87	97	90	106	99	82	90	88	88	104
1 A.	81	86	81	90	75	107	102	72	90	79	80	100
2 A.	76	83	75	80	61	105	89	73	84	92	77	92
3 A.	79	80	77	81	79	96	97	65	85	75	79	93
4 A.	76	78	76	77	67	103	88	66	80	90	77	90
Means	78	82	77	82	70	103	94	69	85	84	78	94
1 AA.	83	82	78	73	75	103	102	76	92	81	79	98
2 AA.	78	77	73	63	48	100	86	72	86	90	82	97
3 AA.	82	77	73	68	51	93	93	69	82	75	81	97
4 AA.	80	73	65	58	51	91	79	61	77	84	76	88
Means	81	77	72	65	56	97	90	70	84	83	80	95
1 AAS.												
2 AAS.												
3 AAS.												
4 AAS.												
Means												
1 C.	80	77	70	66	64	95	87	74	89	103	82	94
2 C.	77	78	70	71	54	94	84	71	89	95	86	95
3 C.	78	75	70	66	58	99	84	70	86	85	79	92
4 C.	78	75	72	66	54	95	81	65	88	90	81	92
Means	78	76	70	67	58	96	84	70	88	93	82	93
1 N.	(84)	79	73	90	76	96	95	67	83	73	76	85
2 N.		73	73	72	69	90	94	64	81	71	79	90
M.				101	85	119	107	86	76	92	89	72
5 O.	(72)	84	77	108	87	118	103	82	77	81	92	96
5 A.	72	86	74	75	67	99	86	64	77	79	74	77
6 {1	85	82	79	102	87	105	111	76	85	85	89	101
6 {2	92	87	82	106	87	106	112	74	83	90	91	100
7	89	84	75	90	75	110	89	74	82	89	77	94

(1) Averages of 4 years, 4 years, and 8 years.

(2) Averages of 9 years (1853–'61), last 10 years,

(4) Averages of 9 years (1853–'61),

Manure, and with different descriptions of Manure. Hoos Field, Rothamsted.

Corn to 100 Straw (and Chaff).

t the period indicated, for particulars of which see *Appendix-Table I.*, and side-notes thereto, p. 179.]

HARVESTS.								AVERAGE ANNUAL.			PLOTS.
1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	First 10 Years, 1852–'61.	Second 10 Years, 1862–'71.	Total Period, 20 Years, 1852–'71.	
96	112	80	85	67	68	102	79	86	87	87	1 O.
103	123	86	101	101	93	110	97	94	100	97	2 O.
102	114	91	85	85	89	97	90	90	95	92	3 O.
104	121	92	88	89	89	101	92	95	98	96	4 O.
101	117	87	90	85	85	102	89	91	95	93	Means
99	114	85	88	83	78	109	82	86	92	89	1 A.
93	109	89	77	97	80	120	85	82	92	87	2 A.
119	105	82	83	84	86	104	78	81	91	86	3 A.
85	101	86	86	85	74	105	76	80	86	83	4 A.
99	107	85	83	87	79	109	80	82	90	86	Means
93	105	82	87	92	74	82	75	85	87	86	1 AA.
89	101	92	71	102	73	100	77	77	88	83	2 AA.
86	101	80	78	87	76	77	74	76	84	80	3 AA.
79	96	93	81	90	69	125	73	72	87	80	4 AA.
87	101	87	79	93	73	96	75	78	87	82	Means
88	78	89	87	87	76	103	82	(¹) 86	87	86 (¹)	1 AAS.
85	98	87	75	92	70	115	72	(¹) 86	87	87 (¹)	2 AAS.
87	101	84	83	84	71	105	78	(¹) 89	85	87 (¹)	3 AAS.
76	96	87	80	90	65	119	68	(¹) 85	86	85 (¹)	4 AAS.
84	93	87	82	88	71	111	75	86	86	86	Means
97	104	97	77	99	82	126	83	81	94	87	1 C.
85	102	100	91	93	77	122	78	78	93	86	2 C.
84	108	92	89	90	76	110	78	77	90	84	3 C.
81	107	92	89	87	78	112	78	76	90	83	4 C.
87	105	95	87	92	78	117	79	78	92	85	Means
87	101	81	79	67	77	132	75	(²) 81	86	84 (²)	1 N.
87	93	85	83	75	72	107	75	(²) 76	85	81 (²)	2 N.
97	109	76	87	67	73	93	78	(³) (95	84	89) (³)	M.
97	108	104	96	91	80	171	77	(⁴) (91	101	96) (⁴)	5 O.
79	97	79	80	92	72	101	78	78	83	80	5 A.
96	121	76	89	72	78	98	75	90	89	90	1 } 6
94	109	89	92	72	75	96	90	92	91	91	2 } 6
88	103	87	86	93	85	123	78	86	91	89	7

and total 19 years.

last 10 years, and total 19 years.

(³) Averages of 7 years (1855–'61), last 10 years, and total 17 years.

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